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THE
FIRST PRINCIPLES
OF
CHEMISTRY.



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OF
CHEMISTRY.

BY
WILLIAM NICHOLSON.

THIRD EDITION, REVISED BY THE AUTHOR.

LONDON:
PRINTED FOR G. G. AND J. ROBINSON,
PATERNOSTER - ROW.

M.DCC.XCVI.

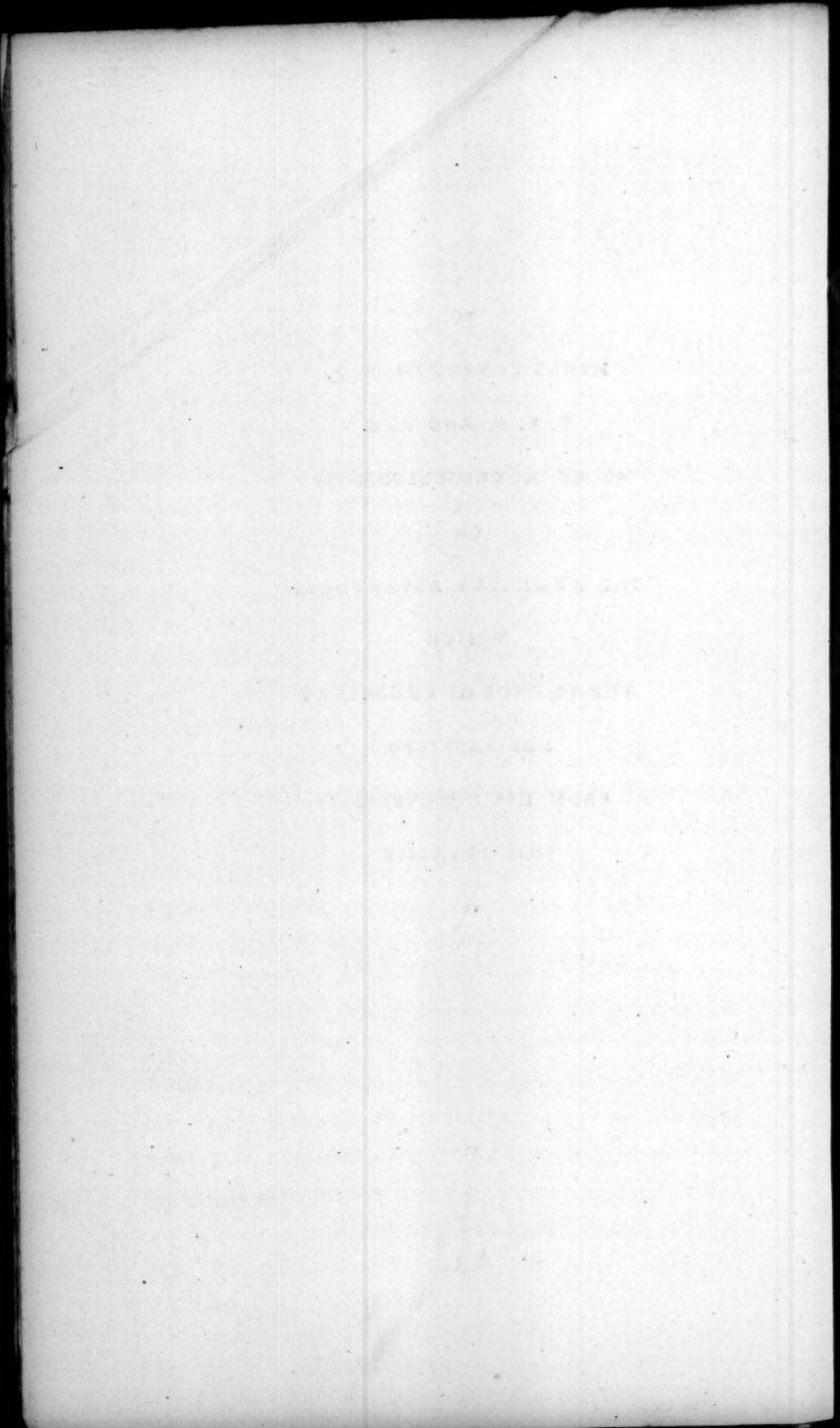
FIRST PRINCIPLES

CHEMISTRY

WILLIAM NICHOLSON



TO
HENRY CAVENDISH, ESQ.,
F. R. S. AND A. S.
AS AN ACKNOWLEDGMENT
OF
THE NUMEROUS ADVANTAGES
WHICH
THE SCIENCE OF CHEMISTRY
HAS RECEIVED
FROM HIS DISCOVERIES:
THIS TREATISE
IS
RESPECTFULLY INSCRIBED.



P R E F A C E.

I HAVE spared no pains in collecting materials for the Treatise I now present to the world: I have condensed those materials into one volume, with more labour than I might have employed in distributing them into two or three: and I have printed it on a page unusually full, at the same time that I have revived an ancient and useful practice of annexing side notes and references; which I believe has fallen into neglect, because it requires great care in the author, uncommon attention in the printer, and adds to the expences incurred by the publisher.

If the work should not therefore prove to be so useful as my intention designed it, the defects will have arisen chiefly from a want of that ability, which he who has it not, can by no temporary exertion attain. The attempt itself is a proof, however, that I indulge expectations of a very different kind,

I believe I *scarcely* need remind the man of science, that the *great* number of labourers in the chemical examination of bodies, has rendered it a difficult task to *collect* the various facts, which lie distributed in the *scts* of academies, and a variety of literary journals. It is not very easy to procure these books : and the perusal of them produces a voluminous table of references ; in which some things may be overlooked, even when noted. A certain degree of imperfection must arise, in every general treatise, from this cause. I have endeavoured to diminish it as much as was in my power.

In treating of facts long since established, and such whose discoverers are unknown to me, I have not quoted my authors ; for, though I would gladly do justice to all claims, yet the investigation of chemical history is foreign to the object of my present pursuit. Whenever I have quoted, it is to be understood that the authors are worthy of credit and respect ; and that the reader will, in almost every instance, find his advantage in consulting them for a fuller account of the subject. But I have quoted these only when it appeared necessary either to complete the information intended to be conveyed, or to clear myself from seeming to lay claim to their discoveries.

With regard to nomenclature and theory, I have attempted to keep clear of every system. I have called things by such names as are most in use, except where the usual name pointed too evidently at theories either long since exploded, or not yet proved : and in the
relation

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relation of facts I have found it much less difficult to exclude theoretical allusions than I at first apprehended, when I formed the determination of confining the theory, for the most part, to the ends of chapters. It would be very advantageous to science if this resolution, which I have adhered to with my best endeavours, were more generally adopted. I do not, however, wish to be thought blind to the advantages of an uniform nomenclature, or a consistent theory; but must urge my conviction that the former ought to be founded on the most incontrovertible facts only, because the nomenclature of any mere theory may be productive of worse consequences than the most confused set of terms can possibly occasion. The systemizing of words, instead of things, is the fruitful source of paralogism; and it is by false reasoning of this kind that a well-methodized hypothesis may be supported, long after the pretended facts are overthrown upon which it was originally built. Upon the two theories of chemistry I have spoken like one who admits neither in any other way than as probable suppositions, which have not yet been experimentally established. The logic of the managers of the controversy for and against phlogiston, appears to me to be exceedingly defective in a great number of instances. The existence of this chemical element is indeed very far from being well ascertained; but, on the other hand, there are many difficulties which attend the consideration of chemical facts without it. As I think the antiphlogistic hypothesis equally probable with the
modified

modified system of Stahl, and more especially as the excellent work of a number of French chemists are written in the language of that hypothesis, I have judged it proper to explain both. And this I have endeavoured to do in such a way, as to create in the chemical student an habit of steadily and calmly attending to the operations of nature ; instead of indulging that hasty disposition for theorizing, which indeed might pass, on account of its evident impropriety, without any earnest censure, if we had not the mortification to see it too much practised by men entitled to the best thanks of the scientific world, and on that account possessing greater power to mislead.

London,
Jan. 25, 1790.

I HAVE carefully revised the Third Edition of this Work : the new discoveries are inserted ; and no exertions have been spared to render it worthy of the distinguished approbation it has met with.

London,
Jan. 25, 1796.

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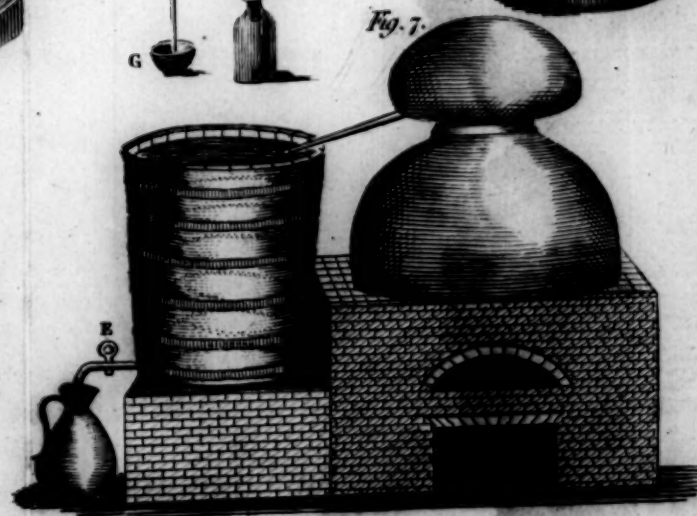
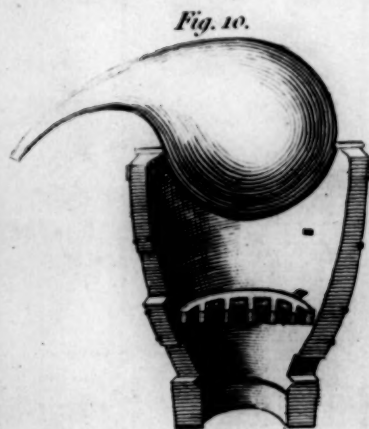
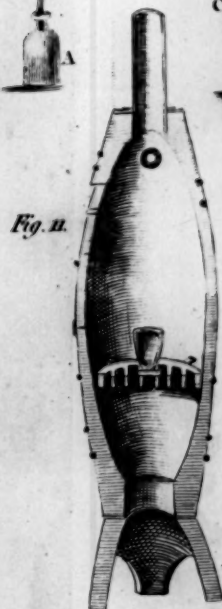
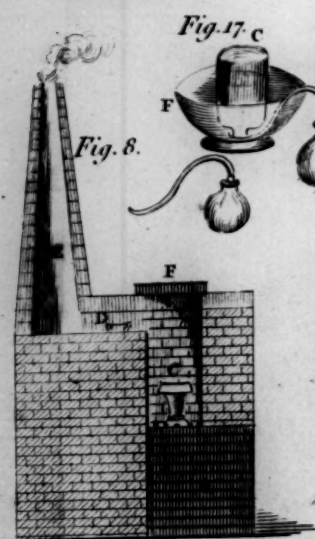
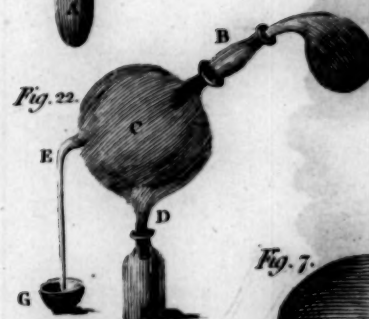
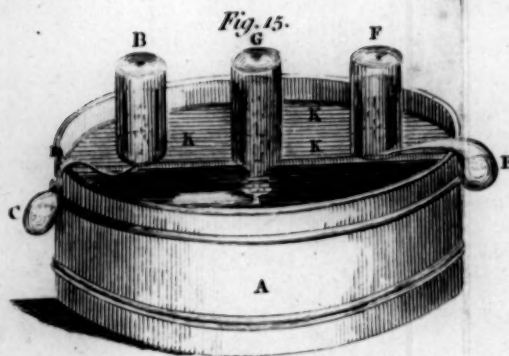
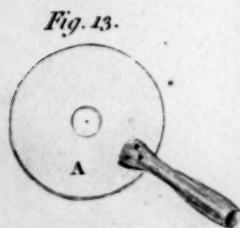
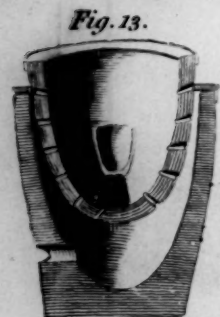
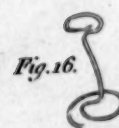
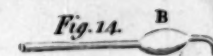
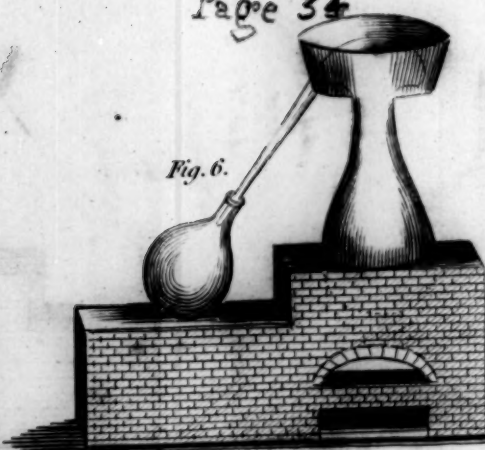
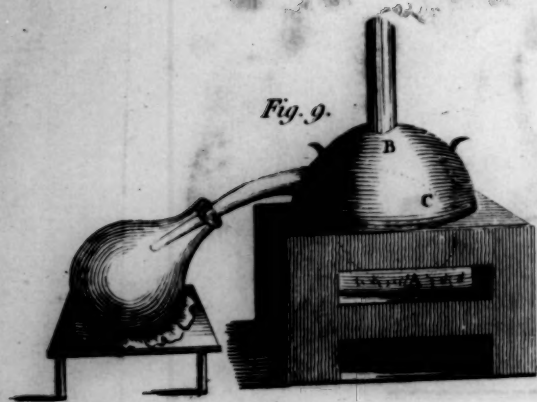


NOTE.

N O T E.

IN the fourth Chapter of the first Book of this Work I had observed in a note, to the first Edition, that very complete sets of small apparatus for experiments with the blow-pipe, and with small retorts and receivers, were sold in London, under the inspection of Mr. Magellan, by Brown, Bookseller, Essex-street, in the Strand. The death of that worthy and active philosopher induced me to cancel the note in the present Edition ; but as Mr. Brown has since acquainted me that he has a considerable number of sets remaining, I think I shall do a service to the Chemical Student by repeating the information in this place.





B O O K I.

GENERAL CHEMISTRY.

C H A P. I.

GENERAL OBSERVATIONS ON CHEMISTRY, AND THE
MEANS BY WHICH ITS OPERATIONS
ARE PERFORMED.

CHEMISTRY may be considered either as a science or an art. As a science, its object is to estimate and account for the changes produced in bodies by motions of their parts which are too minute to affect the senses individually. As an art, it consists in the application of bodies to each other, in such situations as are best calculated to produce those changes.

GENERAL
OBSERVAT.

Chemistry de-
fined.

The operations of chemistry are either analytical, when compounded bodies are resolved into their simpler parts; or synthetical, when simple bodies are united so as to form a compound. The former operation is called decomposition; and the latter composition, or combination. There are few, and perhaps no chemical processes, in which one of these effects takes place without the other.

Heat expands solids, then renders them fluid, and afterwards converts them into vapour; and these

B

changes

GENERAL
OBSERVAT.

Heat.

changes succeed each other as the intensity of the heat is rendered greater. There are many bodies not susceptible of all these changes: but it is highly probable that this is owing to our want of power to produce a sufficient degree of heat or coldness, and not to the peculiar nature of the bodies themselves.

Analysis by
heat.

The heat required to render different bodies fluid or elastic, being different, affords a method of separating the parts of compound bodies. If one part of a compound body be rendered fluid, while the others remain solid, the former will flow into the lower part of the containing vessel, and leave the pores of the latter empty: or if one part be converted into vapour, it will rise and fly off, leaving the other parts, whether solid or fluid, in the vessel. Thus, when a mixture of lead and copper is exposed to a gradual heat, the lead melts first, and leaves the copper. And if a mixture of water and salt be heated, the water being converted into vapour, flies off, and leaves the salt behind.

Attraction.

All the parts of bodies attract each other. It is not necessary in this place to enquire, whether that attraction which causes bodies to gravitate or have weight, and by the energy of which the great motions of the planetary systems are governed, be the same as the attraction which causes their parts to adhere, and gives them firmness or solidity. It is enough that observation has not yet established the truth of this proposition; and, consequently, it will be proper to consider the attraction that is perceived to obtain in chemical operations, as a distinct property of matter.

The attractions which are observed in chemistry, are not found to have efficacy at any sensible distance
between



between the parts; but doubtless, like the attractions of gravity, magnetism, and electricity, they are stronger the less the distance. The rigidity and permanent forms of solid bodies prevent many of the parts of two several bodies from coming near each other: for which reason, very little change is in general produced by their mutual action, even in the most favourable case, when powders are mixed together. But when one or both of the bodies is heated so as to become fluid, the particles easily move among each other; and can more readily obey the attractions which exist between them. Hence it has been considered as a chemical axiom, that bodies do not act on each other, unless one of them be fluid.—This assertion is liable however to the exception, that solid bodies will combine at a temperature too low to render either of them fluid, provided it be high enough to fuse the compound they form. Thus ice and salt will combine at a much lower temperature than would liquefy either alone, if the temperature be not so low as to freeze the brine they form by uniting.

GENERAL
OBSERVAT.

Chemical attractions

—act by means of heat.

The whole art of the chemist therefore consists, either in separating the parts of bodies by the application of heat, or in placing them so that the order of arrangement of their parts may be changed by virtue of their several attractions, assisted by heat sufficient to fuse one or more of them, or at least sufficient to produce fusion in the compound.

Art of the chemist.

Since the order of arrangement of the parts of bodies is changed, when the chemical attractions are permitted to act, by a due situation of bodies with respect to each other; it clearly follows, that the attraction between some kinds of bodies is stronger than between

Elective attractions.

GENERAL
OBSERVAT.

Dry and humid
way.

others. This difference was formerly supposed to proceed from a similitude between the attracting bodies, and for that reason the attraction has been called the chemical affinity of bodies. But the term elective attraction is at present more generally used to denote this property.

Though the operations with bodies that require a very strong heat to render them fluid, do not essentially differ from those which are made with such bodies as are fluid at the usual temperature of the atmosphere; yet, as the apparatus for producing and maintaining the heat in the former case is unnecessary in the latter, it is found convenient to distinguish the two methods by different appellations. Operations made with bodies habitually solid, which of course require to be acted on by a strong heat, are said to be made in the dry way; but operations wherein any substance is employed which is habitually fluid, are said to be made in the liquid, humid, or moist way. No distinctive appellation has yet been generally adopted for operations made with elastic fluids; though some call this the pneumatic method.

Terms of art.

In every science or art there are many things which require to be frequently mentioned. If these were described as often as they are mentioned, it is obvious that a great loss of time would follow; and no advantage would be gained in perspicuity, because these descriptions would continually divert the mind from the leading object. For this reason it is absolutely necessary to express such things by single words or terms, which, when once understood, may always afterwards be used in the same sense. These will be explained in the following treatise as they occur.

CHAP. II.

ON HEAT.

THE sensations expressed in common language by the words heat and coldness, are of too simple a nature either to require or to admit of definition. HEAT.
Of the word heat. These words, however, are not always used to denote the same things; but are indiscriminately applied both to the sensation itself, and to that which causes it. Thus we say that we ourselves are hot or cold, and that the fire or ice which heats or cools us is likewise hot or cold, though the sensations we experience are certainly very different things from that which enables bodies to excite them. It may also be remarked that, in this ambiguous manner of speaking, there is another cause of uncertainty, that arises from the use of a variable standard of comparison. Every one knows that the estimate of heat or coldness differs in various persons, because each forms his judgment from his own sensations: and the same body may appear hot to one person, and cold to another, or to the same person at different times; though the variation is not in the body itself, but in the state of the persons in whom those sensations are excited. Hence it appears necessary, in order to avoid error in the pursuit of enquiries concerning heat, that the sense of the words made use of should be accurately defined; and that some fixed standard of comparison be referred to instead of the human body, which, though fixed enough for the common

HEAT.

affairs of life, is certainly not enough so for the purposes of science.

Word heat.

The word heat, in a philosophical sense, is used to denote the cause of the power which bodies possess of exciting the sensations of heat or coldness.

Temperature.

The word temperature denotes the state of the body with respect to that power. So that a body which excites a more intense sensation of heat or coldness than another body, is said to possess a higher or lower temperature.

Cause of temperature.

It has not yet been determined in what heat itself, or the cause of temperature, consists. Two opinions have long divided the scientific world. One is, that heat consists of a peculiar motion or vibration of the parts of bodies, so that the temperature is higher the stronger the vibration : the other is, that heat is a substance or fluid, whose greater or less quantity produces a higher or lower temperature. Though the decision of this great question is highly deserving of the attention of philosophers, yet it will not be necessary to consider its merits in this place ; and that more especially, as the doubts respecting it will not impede our reasoning concerning such phenomena as are well known. For since effects are proportioned to their adequate causes, we may speak of the quantities of heat in bodies, without deciding whether they be quantities of motion or quantities of matter ; the relations of those quantities to each other, and not their peculiar nature, being the chief object of our research.

Common temperature.

Two bodies which, when in contact, neither impart nor receive heat from each other, are of the same temperature.

perature: All bodies, therefore, which by direct or successive contact communicate with each other, must either have the same temperature, or the hotter will communicate heat to the others, till a common temperature is produced amongst them. HEAT.

The disposition or power of quickly transmitting heat in the production of a common temperature, is not the same in different bodies. If a number of straight wires of equal sizes, but different metals, be covered each with a thin coat of wax, and their ends be all plunged in the same heated fluid—for example, melted lead—the fusion of the coat of wax will shew that heat is more quickly transmitted through some metals than others. Thus also it is found, that the end of a glass rod may be kept red-hot for a very long time, without any inconvenience to the hand which holds the other end; though a similar metallic rod, heated in the same manner, would very soon become too hot to be held. Bodies that quickly alter their temperature by communication, are said to be better conductors of heat than such as alter more slowly. Conductors of heat.

The general effects of a change of temperature are these:—A solid is rendered fluid by an increase of temperature, and a still greater increase converts it into elastic fluid or vapour. If the body be composed of parts which become solid, fluid, or vaporous, at different temperatures; and the elective attraction by which those parts are held together be insufficient to prevent their assuming those states by the change of temperature, a separation will then take place: thus a diminished temperature separates many salts from water, by their becoming solid; and an increased temperature se-

HEAT.
Expansion by
heat.

parates water from salts, by causing the former to fly off in vapour. Lastly, if neither the change of temperature be considerable enough to alter the state of solidity, fluidity, or vapour, which the body under consideration may happen to possess; nor the body itself be of that nature as to undergo a separation of its parts by the change; then an increase of temperature will cause an increase in the bulk or dimensions of the body, which will last no longer than during the time of the increase.

Changes by
heat do not fol-
low the density,
&c. of bodies.

It has already been observed, that the temperature at which different bodies change their form, is various. Neither this property, nor the expansions of bodies by heat, have been observed to have any correspondence with their density, hardness, specific gravity, or other evident properties. There are likewise some irregularities in the contraction or expansion, which depend on circumstances not yet well ascertained, near the freezing point of water, and probably other substances. Pure water, when cooled, is observed to contract till within about 8 degrees of the freezing temperature, where it begins to expand; and it may be cooled 11° below that temperature, and still continue fluid. An adequate explanation of the circumstances that attend the conversion of bodies from their several states, of solidity, fluidity, and vapour, seems to promise a more intimate acquaintance with the nature and properties of the particles of bodies than has hitherto been obtained.

Elastic fluids.

Permanently elastic fluids, or airs, appear to differ from vapour in the circumstance that they take and retain the elastic form at a lower temperature. There are

are facts which render it probable, from analogy, that a great degree of cold would convert them into dense fluids.

HEAT.

It is a self-evident truth, that if two bodies be perfectly equal and alike in all respects, and have the same temperature, they will possess equal quantities of heat. Thus, a pound of gold will possess an equal quantity of heat with another pound of gold, at the same temperature; a pound of water will possess an equal quantity of heat with another pound of water, at the same temperature; and so forth. From this it will also be clear, that two pounds of gold will possess twice as much heat as one pound of gold, at the same temperature; and, generally, that the quantities of heat in bodies of the same kind, and at the same temperature, will be in proportion to their quantities of matter or their weights.

Quantity of heat in equal bodies:

If two such equal and similar bodies, that differ in temperature, be brought together, they will by communication acquire a common temperature, and their quantities of heat will by that means be rendered equal. For this purpose it is clear that the hotter of the two bodies must have communicated half its excess to the colder: the quantity of heat in one of these two equal bodies will therefore be an arithmetical mean between the two quantities originally possessed by each of them; that is to say, its temperature, or the common temperature, will exceed that of the colder exactly as much as it falls short of that of the hotter body.

—differing in temperature

If the two bodies had been unequal, they would nevertheless have acquired a common temperature by communication, but the excess of heat would not have been

—in unequal bodies.

HEAT.

been equally divided between them; for we have shewn that the quantities of heat in such bodies, at the same temperature, are in proportion to the quantities of matter. If the surplus of heat had been entirely taken away, it is obvious that their temperatures would have been made equal, and their heats would have been in that proportion; and there is no other way of adding the surplus to them, so as to preserve the same proportion, but by giving more to the larger than to the smaller body, according to its quantity. The common temperature they acquire shews that this is done; and consequently that, when two unequal bodies of the same kind acquire a common temperature by communication, the excess of heat in the hotter body is divided between them in proportion to their weights or quantities of matter.

Quantities of heat required to change temperature.

From this it is likewise evident, that the quantities of heat required to be added to or taken from bodies of the same kind, to produce equal changes in their temperature, will be in proportion to their quantities of matter.

Thermometer;

The foregoing deductions naturally lead us to the consideration of an instrument proper to shew the temperatures of bodies. Such an instrument will require to be placed in contact with the body under examination, in order that it may acquire the same temperature. It is therefore an indispensable condition, that the instrument should be of that small bulk as not sensibly to heat or cool the body it touches; but that the common temperature of the instrument, and the body itself upon contact, may, without perceptible error, be taken for the original temperature of the body.

—its requisites.

body. Another condition equally requisite is, that every change of temperature shall be attended with some evident change in the instrument by which it may be ascertained. The expansions and contractions of bodies are the most convenient for this purpose. These, however, are small; and would require to be magnified by some mechanical or optical contrivance, if a solid body were made use of. But the smallest change in the bulks of fluids may be easily shewn by the happy expedient of including them in a bottle whose neck is long, and very narrow, in proportion to the diameter of its body. On these considerations the HEAT.
Mercurial thermometer.
 thermometer is made. It consists of a glass ball or bottle, with a long narrow tube or neck, and is partly filled with mercury; a fluid preferable to all others, from its unchangeableness, the regularity of its expansions, and its not soiling the tube. The expansions or contractions of the mercury are shewn by the rise or fall of its surface, which is measured by a graduated scale usually fixed to the tube.

The determination of the correspondence between the degrees of the thermometer, and the actual variations of the heat of fluids, was first accurately determined by Mr. De Luc. By mixing equal quantities of water at different temperatures, he found that the thermometer very nearly indicated the arithmetical mean between the two temperatures, and consequently that its indications are such as truly correspond with the quantities of heat. Correspondence of the expansions of mercury with the increments of heat ascertained by De Luc;

As these fundamental experiments cannot be too strictly examined, the following doubt remained to be considered, nameiy, whether the disposition to give out

—by Crawford.
 or

HEAT.

or to receive heat, were the same in water at all temperatures; because it is clear that, if this disposition be changed by heating or cooling, the temperature, or power to heat or cool other bodies, will not follow the same proportion as the quantities of heat; though it may be imagined, not without probability in this case, that correspondent irregularities in the expansions of the mercury, may cause the thermometer to indicate the arithmetical mean between the two expansions produced by any extreme temperatures. But whatever irregularities may be supposed to counteract each other in these experiments with mercury and water, it is to the last degree improbable that the same compensation would be found, when the mean temperature is obtained by other methods. With this view the celebrated Dr. Crawford * very carefully repeated and confirmed Mr. De Luc's experiments; made others with a like result, by using linseed oil instead of water, and also by producing the mean temperature, permanently, in air included in a cylinder formed of two equal parts, the upper of which was kept to the freezing point, by surrounding it with pounded ice; and the lower to the boiling-water point, by surrounding it with a greater supply of steam than could be condensed by its contact. The near correspondence of these several methods shews that the expansions of the mercury in the thermometer are correspondent with the heat it receives.

* On Heat. London, 1788. This most valuable performance contains the theory, and most of the facts, relating to heat; and deserves to be made a part of the library of every natural philosopher.

Thus

Thus far we have attended only to the communication of heat between bodies of the same kind; but when two equal bodies of different kinds produce a common temperature by communication, it seldom happens that it proves to be an arithmetical mean between the two original temperatures. In such cases it is evident that the heat which was communicated from one to the other, has not altered their temperatures equally, but has raised or lowered that of the one more than it has lowered or raised that of the other. And as the proportion between the number of degrees through which one of two bodies is thus raised, and the other lowered, is found by experiment to be the same, however different the two original temperatures may have been, provided no change of form or chemical combination has been produced in either of them; it is a general consequence, that the quantity of heat required to alter the temperature of one of the bodies a single degree, or any other equal part, will be greater or less than would be required to produce the same change in the other body, in proportion as the changes produced by the communicated heat were less or greater.

HEAT.

Quantities of
heat in bodies
of different
kinds :
—relative.

The whole heat in each body, when they have the same temperature, must consist of the same number of degrees: the proportion between the whole heats of the bodies will therefore be the same as between the heats required to raise each of them a single degree: that is to say, the comparative heats of bodies, at the same temperature, will be in the inverse proportion of the number of degrees their temperature is altered by the same quantity of heat.

To illustrate this by an example in round numbers. Example.

Suppose

HEAT.

Suppose a pint of mercury, at the temperature of 136° , be mixed with a pint of water at 50° , the mean temperature will be 76° . The water therefore has been heated 26° ; and the mercury has been cooled 60° , by the loss of the heat it imparted to the water. The absolute heat in one degree of the mercury will consequently be proportionally less than that of one degree of the water; because the very same heat which has raised the water 26 degrees in temperature, would raise the mercury 60, if it could be returned again: and the whole heat contained in the mercury will be to that of the water in the same proportion of 26 to 60. But in the present experiment equal bulks were used; and mercury is about 13 times as heavy as water. An equal weight of mercury would contain only one-thirteenth part of the heat. Twenty-six, divided by 13, quotes 2: whence the comparative heats of mercury and water are in the proportion of about 2 to 60, or 1 to 30; that is to say, a pound of mercury, at the same temperature, contains no more than one-thirtieth part of the heat contained in a pound of water.

Comparative heat.

It may be observed that the term comparative heat is used to denote the proportion of the absolute quantity of heat in one body to that of another equal mass of matter, at the same temperature, considered as a standard. The standard made use of is pure water, in a fluid state. Some writers call this specific heat. The disposition, or property, by which bodies severally require more or less heat to produce equal changes in their temperature, is called their capacity for heat. These capacities are considered as the unknown cause of the differences in their comparative heats, to which they are consequently proportional.

Capacity.

It is found, by experiment, that the capacity of the same body for heat is least when solid, greater when fused or fluid, and greatest of all when it becomes converted into vapour, or elastic fluid.

HEAT.

Capacities in various states.

Also, when bodies unite by virtue of chemical attraction, their capacities are seldom the same as the sum of the capacities of the bodies, but almost always either greater or less.

—changes by chemical actions.

As the experiments relating to the capacities of bodies cannot be here given at large, it will be proper to mention, by way of inference, some of the chief consequences of this most luminous doctrine; first premising, however, that these inductions have all been verified by experiment*.

Inferences.

The capacities of ice and fluid water are found to be as 9 to 10. Ice cannot therefore be converted into water, unless it be supplied with as much heat as is sufficient to answer the difference of capacity. Thus, if equal quantities of ice and water, both at the temperature of 32° , or the freezing point, be exposed in similar vessels, at the same distance from a fire, both will receive heat alike; and the ice will be melted into water at 32° , while the water in the other vessel will have its temperature raised to 178° . Here it is obvious that the same heat which raised the water 146 degrees, was merely sufficient to supply the increased capacity of the ice; for which reason this last had not its temperature raised at all. If the experiment be more accurately made, by mixing equal weights of water at 178° , and ice at 32° , the same consequence will follow;

Ice and water.

* For which consult Dr. Crawford's Treatise, already spoken of.

HEAT.

for the ice will be melted, and the common temperature will be 32° ; because the ice in melting receives no augmentation of temperature, but absorbs the whole 146° of heat from the water, by virtue of its increased capacity when it becomes fluid.

Stationary temperature, or freezing point.

And so likewise, when water is frozen by the loss of its heat, communicated to a cold atmosphere, or other contiguous bodies, the process of cooling goes on till ice begins to be formed: but, during the whole time of the conversion of the water into ice, the temperature remains stationary, because the diminished capacity of the ice causes it to give out heat, the continual evolution of which supplies the refrigerating bodies with as much as their energy of cooling might otherwise have taken to cause a diminution of the temperature. When the whole is frozen, this supply of extricated heat ceases; and therefore the cause that cooled the water at first, goes on in cooling the ice, until the common temperature is produced.

Natural zero of temperature.

In all experiments wherein the capacities of the same bodies are changed, and the difference between the quantities of heat in the same body in both states, at one common temperature, is known in degrees of the thermometer, we may derive the advantage of finding the absolute quantities of heat in degrees of the thermometer, or the number of degrees which any particular point or temperature is remote from the true zero, or point of absolute privation of all heat. To illustrate this curious position, the experiments on ice and water, just related, may be made use of. The whole quantities of heat, in these two states, are as 9 to 10. It is plain, therefore, that when water freezes,
it

it must give out one-tenth of its whole heat; and this tenth part, by the experiment, is found to answer to 146° of Fahrenheit's thermometer. Consequently its whole heat is ten times 146° , or 1460° of Fahrenheit's thermometer, when its temperature is 32° above Fahrenheit's zero. Whence the natural zero* is at -1428° .

HEAT.

No direct experiment has yet been made to shew the capacity of steam with relation to water. An indirect experiment of Dr. Crawford makes it as $15\frac{1}{2}$ to 10†. It is accordingly found that steam, in its condensation into water, gives out as much heat as would raise an equal quantity of non-evaporable matter, of the same capacity as water, 914 degrees. This heat it must have taken up at its formation. Whenever water is heated, we may consequently consider the heat as disposed of in two ways. One part raises the temperature of the fluid water, and the other part is employed in supplying the elastic vapour that flies off with the heat which its increased capacity requires at that temperature. The greater the quantity of steam is produced, the larger will be the proportion of the heat employed in this last way. Now, there is a difficulty attends the formation of elastic vapour, in proportion as its escape is rendered more difficult. If the water be heated in a close vessel, no steam will be formed; if the steam escape by a small hole, there will be less formed than if the whole surface of the water were uncovered; and if the superincumbent atmosphere be removed, as in the vacuum of an air-pump, the production will be greatest of all. As the heat of the

* Crawford, p. 458.

† Ibid. p. 270.

HEAT.

Boiling-water
point of tem-
perature.

water goes on increasing, the production of steam will likewise increase, until the quantity is so great as by its augmented capacity to carry off the whole heat that is communicated. At this period the increase of temperature will therefore cease, and the temperature will become stationary. This point is called the boiling-water point. It varies, however, a little, as the pressure of the atmosphere varies, being lowest when that is least; because the maximum of steam is produced at a lower temperature when the obstacle to its escape is less. It has been stated, and with some probability, that there might be no interval of fluidity between the solid and vaporous forms, if it were not for the pressure of the atmosphere.

Evaporation
produces cold.Freezing by
evaporation.

In this manner it is easy to account for the cold produced by evaporation: for the volatile substance, when it takes the vaporous form, absorbs as much heat from the body from which it evaporated, as its increased capacity requires. Every one must be acquainted with the cold produced by wetting the hand with water or with spirits of wine or brandy. The freezing of water by means of the evaporation of ether, is a very remarkable instance of this. Water is included in a thin glass tube, and the outside of the tube is kept continually wetted with ether, by means of a bottle with a capillary tube in its neck, through which the ether is poured. The consequence of the speedy evaporation of this very volatile fluid is, that in a very short time the included water is suddenly converted into ice, even before a fire, or in the midst of summer.

Freezing mix-
tures.

The effect of freezing mixtures is another evident consequence of this doctrine. When as much com-
mon

mon salt is added to water as it can dissolve, the brine continues unfrozen till it is cooled as low as 6° below 0° , on Fahrenheit's scale. Suppose pounded ice, or snow, to be mixed with salt at any temperature above -6° , their union will produce the brine here mentioned; which, because the heat is above its freezing point, will become fluid, though the ice and salt were solid before. This fluidity will be attended with an increase of capacity, and therefore the brine will be much colder than the snow and salt were. If the quantity of snow and salt be considerable, and there be no bodies at hand which can readily supply heat, the brine first produced will cool the snow and salt in its vicinity; and this, when liquefied, will cool the rest of the snow and salt still more effectually. When the temperature of the whole is as low as -6° , or the freezing point of the brine, the liquefaction and cooling will stop, or it will proceed more slowly or faster, in proportion as the requisite heat is supplied. It may easily be imagined that, if a mixture of this kind be placed in a vessel, and a smaller vessel, containing water, be plunged in it, the cooling process will freeze the water. It is likewise evident that such mixtures will descend to a fixed temperature, which is that of their own freezing point*.

HEAT.

Fixed temperature of freezing mixtures.

So likewise the freezing processes by the solutions† of salts in water or acids, though they have not yet been so minutely examined, may be explained from the difference of capacity produced in the liquefaction of solid salts, or the water contained in them. One of

Freezing processes by dissolving salts in water.

* Crawford, p. 474.

† Walker, in *Philos. Trans.* vol. lxxvii and lxxviii.

HEAT. these may be here mentioned, not as the most powerful, but because the materials are cheap, and well known. It consists of equal parts of sal-ammoniac and saltpetre, finely powdered. If four ounces of water be poured on three ounces of this mixture, the solution will sink the thermometer 36 degrees; and as it is easy to have pump-water as cool as 50° in the midst of summer, this addition will cool it to 14°, which is therefore sufficient to freeze water in a phial plunged in it.

Mixture of salts for freezing water.

General view of the agency of heat.

Advantages arising from the changes of capacities.

Without entering more largely into examples of the consequences of the change of capacity in bodies which are changed in their form, or state of chemical combination, it may be observed, in general, that as the powers of gravity, and projection, in continual opposition to each other, produce all the beautiful effects in the great system of the universe to which they are essential; so, among the actions of the minute parts of bodies, the cohesive attraction, and the energy of heat, are in continual opposition to each other, and are concerned in every process by which changes are produced in the peculiar properties of bodies: and for whatever more immediate purposes it may be that the Supreme Intelligence has thus generally appointed their agency, we see that the changes of capacities are greatly conducive to the preservation of a more equal temperature than would otherwise be found in the districts around us. The cold produced by evaporation greatly mitigates, and conducts to other parts, the strong heats of the torrid zone; and the heat developed on the freezing of water prevents the cold from falling so far below the freezing point as otherwise it might do.

HEAT.

do. If the capacities of water and ice were equal, the freezing of immense bodies of water would scarcely be progressive, but would take place the instant the whole was cooled to 32° ; and so likewise the thawing of vast tracts of snow and mountains of ice would be performed in the short time of the transmission of the heat required to raise its temperature the minutest portion of a degree above the temperature of solidity. Whether the extreme inconveniences the hotter climates would undergo from increased heat, or the colder from the intense freezing and sudden thaws, be among the principal events in the view of the Sovereign Disposer of the universe, cannot, from our ignorance of final causes on so large a scale, be determined.

Whether heat be matter or motion, is a question which, as was before observed, is not well settled. It is certain that the motion of friction, or percussion, either produces or collects heat; and if the supposition of the mere vibration of parts could adequately account for the effects, it would doubtless be more simple than to call in the assistance of a material substance endued with peculiar properties. But, on the other hand, the appearances are solved with great ease and simplicity by the supposition of such a substance. On this subject it may perhaps be sufficient to observe, that the phenomena of heat seem to stand single, so as not easily to admit of comparison with any of the other appearances in nature; and consequently that all reasoning by analogy promises very little elucidation of a subject which can only be prosecuted by experimental research.

Question, p. 6.

The philosophy of heat admits no analogy.

HEAT.

Diminution of
capacity in-
creases weight.

Attempts have been made to determine whether the weight of bodies is affected by the greater or less quantity of heat they may contain. The most accurate experiments shew that the same water is heavier, by a very minute quantity, when it is converted into ice.

Dr. George Fordyce made the experiment by weighing the same quantity of water (about 1700 grains), when frozen and when unfrozen, at the temperature of 32° , in a room where the air was of the same temperature. The ice was near one sixteenth of a grain heavier. Phil. Transf vol. lxxv. p. 362—Sir Benjamin Thompson obtained the same conclusion, by counterpoising water against spirit of wine, and exposing the apparatus to a cold atmosphere which froze the former.

C H A P. III.

THE CONSTRUCTION OF THE THERMOMETER.

IN the present cultivated state of philosophical knowledge, it can hardly be supposed that the reader has not seen a thermometer. Minute description is therefore unnecessary. But as the accurate construction and subsequent improvement of this instrument must greatly depend on the knowledge, which those who use it may possess, of the method of making it; and as we have no perfect account of this, there can be no doubt but a short relation of the whole process, from experimental knowledge, will be acceptable.

THERMOMETER.

Construction of the thermometer.

The tubes may be had at the glass-house; and the first care of the artist must consist in examining if their cavities be equal or cylindrical throughout. This is done by immersing one end into mercury, and withdrawing it, after closing the other end with the finger. By this means a small quantity of mercury will enter the tube, which will occupy a longer space the deeper the tube is immersed. Lay the tube horizontally upon a graduated rule, and observe the length of the mercurial column, in different parts of the tube to which it may be made to run, by inclining it more or less. If the length continues invariably the same, it is a proof that the tube is uniformly cylindrical; but, if otherwise, the diameter varies, and the tube cannot be used to make a good thermometer, unless the graduations in the different

To determine the cylindrical form of the bore.

THERMOME-
TER.

Method of
blowing ther-
mometers.

ferent parts of the tube be lengthened or shortened, in proportion to the measures of the mercurial column.

Direct the flame of a large candle, a watchmaker's lamp, or, which is cleanliest and best of all, a lamp with spirits of wine, upon one end of the glass tube, by means of the blow-pipe. The extremity will soon become red hot, and in a state of imperfect fusion. Remove the tube from the flame, and blow into its other end, and the heated part will be inflated so as to form a bulb. This last inflation is the most difficult and laborious part of the business; but it may be performed with great ease and advantage, by previously fastening the neck of one of the small bottles of elastic gum, or India rubber, about the end of the tube; which, when the other end is ignited, may be pressed by the hand, so as to blow the bulb very commodiously, and without the introduction of any moist air.

Filling with
mercury.

Immerse the open end of the thermometer tube into some very clean dry mercury that has been boiled, and warm the bulb with a candle; part of the air will be immediately heard rushing through the mercury; withdraw the candle, and, as the bulb cools, the mercury will rise in the tube. This will be facilitated by holding the tube as near an horizontal position as can be done, without raising its lower end above the surface of the mercury. In this way the bulb will be nearly half filled. Without altering the position of the apparatus, move the whole so that the bulb may be held over a candle. A small candle newly snuffed is best, because of the steadiness of its flame; and it will be necessary to wrap a piece of paper round the tube, to defend

defend the finger and thumb from its heat. The mer- THERMOME-
TER.
cury will soon boil, and most of the remaining air will be heard escaping from the bulb. As soon as this escape has ceased, remove the bulb from the candle, and it will be suddenly filled with mercury from the vessel.

Take the thermometer thus filled out of the mer- Boiling the
mercury in the
tube.
cury, and wrap round its open end a piece of thin paper, in such a manner as to leave a cavity beyond the tube, at least sufficient to hold as much mercury as the bulb contains; secure this by wrapping it tight with packthread about the tube; then put a drop of mercury into the paper cavity, and apply the bulb again over the snuffed candle, holding the tube upright between the finger and thumb, or a pair of small pincers, at the part wrapped with paper and packthread: the mercury will soon boil, and about half the contents of the bulb will rush violently up the tube into the paper. Remove the bulb from the candle, and the mercury will suddenly return; then boil it again; and repeat the operation till the speedy boiling of the mercury, when placed over the candle, and the diminished noise and agitation, shew that the whole has been well heated, and deprived of the air or moisture which might have adhered to it.

The operation of boiling will fail, if the mercury, Caution.
or the inside of the bulb, be moist; for in this case the bulb is usually burst by the mercurial vapour; the explosion however is not dangerous: it is very likely to happen with bulbs blown by the mouth, unless they be kept some weeks in a dry place, before they are filled. The same danger makes it prudent not

THERMOME-
 TER.

to boil the mercury strongly the first or second time; and it is likewise of importance to keep the bulb clear of the flame, as the contact of this last against the empty part of the bulb would melt it, and a hole would be immediately made by the excluded vapour.

Trial of the
 proportion be-
 tween the bulb
 and the tube.

After the boiling is completed, plunge the bulb into cold water, whose temperature is known. Melting ice or snow (or snow and water) always has the temperature of 32° of Fahrenheit's scale. Then take off the paper, and put the bulb into the hand, and afterwards into the mouth; this heating will cause some of the mercury to drop out of the tube. Cool it again to 32° , by immersing it in the cold water, and mark where the mercury stands. The distance between this station and the top of the tube measures the interval between freezing and blood heat, or 32 and 95, which makes 63 degrees; and will consequently shew whether the degrees will be large or small, and what extent the scale is capable of; that is to say, it will shew whether the bulb is of the proper size. This last, supposing the judgment of the operator not sufficient to proportion the bulb nearly to the tube, and the intended scale, might however have been more conveniently ascertained after the first filling, before the boiling had been undertaken.

Hermetical
 sealing of the
 tube.

When the number of degrees to which the length of the tube will extend is thus known, the operator must settle whereabouts he will have the freezing point, which may be nearer or farther from the bulb, accordingly as he intends the instrument to be used, more particularly to ascertain great degrees of heat,

or

or of cold. At this stage of the business, likewise, he may heat the upper part of the tube with the blow-pipe, and draw it out to a fine capillary tube ready for sealing. The bulb must then be heated in the candle, till a few particles of mercury have fallen off the top of the tube; and notice must then be taken how much nearer the freezing point is to the bulb than before, which may be done by immersing it in the melting snow, as before. If it be not as low as desired, the heating must be repeated, carefully observing not to throw out too much mercury at a time. When the due quantity of mercury is thus adjusted, two candles must be prepared, the one to heat the bulb, and the other to close the tube. The blow-pipe being in readiness, the upper part of the tube near the flame of one candle, and the bulb near the flame of the other, the mercury will rise, and at last begin to form a globule at the point of the capillary tube. At this instant the bulb must be withdrawn from the lower candle, at the same time that the flame of the upper is directed by the blow-pipe upon the point of the tube. This last will be immediately ignited, and will close by the melting of its parts, before the mercury has perceptibly subsided. When the mercury has fallen, this closure may be rendered more secure from accidental breaking, by fusing the whole point of the tube, till it becomes round.

If this business be properly done, the mercury in the instrument thus filled will run backwards and forwards in the tube, immediately upon inverting its situation.

Proof of internal vacuum.

In

**THERMOME-
TER.**

Adjustment
of the fixed
points.

Freezing.

Boiling.

In the original graduation of thermometers, two fixed points of temperature are necessary. These are the freezing point of water, or temperature of ice or snow, at the instant of formation, or rather when it is just beginning to liquefy; and the boiling point of water, or temperature at which, under a known pressure, it is plentifully converted into steam. For the settling the freezing point, nothing more is necessary than to immerse the thermometer so deep in melting snow or ice, as that the mercury may be barely visible above its surface, and carefully mark the place at which it stands. The boiling point is not quite so easily ascertained; crude, hard, or saline waters acquire a greater heat in boiling than such as are purer; and the same water will acquire a greater heat under a greater pressure. For this last reason, the boiling point should be fixed according to the decision of the committee of the Royal Society; namely, when the barometer stands at 29.8 inches. The best method is to provide a vessel somewhat longer than the thermometer, with a cover, and two holes in it; one about an inch in diameter, for the steam to escape; and the other smaller, for the thermometer tube to be fastened in it. When this is used, the thermometer must be fastened in the cover, so that the estimated place of the boiling point may be just above the hole. Water must be put in the vessel, not sufficient to touch the bulb of the thermometer, when the cover shall be put on. The vessel must then be covered, a thin plate of metal laid on the steam-hole, and the water made to boil by heat applied to the bottom only. The thermometer will be then surrounded with steam, which will raise its temperature

perature to the boiling point; and this point must be carefully marked on the tube. The following method may be more convenient to those who are not provided with such a vessel:—Wrap several folds of linen rags or flannel round the tube, nearly as high as the supposed boiling point; hold the ball of the thermometer in the ascending current of boiling rain water, about two or three inches below the surface; pour boiling water on the rags three or four times, waiting a few seconds between each time; and wait some seconds after the last time of pouring on water, in order that the water may recover its full strength of boiling, which is considerably checked by the pouring on the rags. The place where the mercury stands is the boiling-water point.

THERMO-
METER.

Notwithstanding the accurate adjustment of the fixed points of a thermometer, yet if the tube be not truly cylindrical, or if the divisions be not adjusted to the inequalities of its diameter, the errors at the middle, between the two fixed points, may amount to more than a whole degree. A small error in the standing of thermometers may be occasioned by the varying pressure of the atmosphere, which alters the capacity of the glass; but it never amounts to so much as the tenth part of a degree. Spherical bulbs are least subject to this.

Adjustment for
errors of the
tube.

Thermometers which, from the great length of their degrees, or for any other reason, are made to take in but a small part of the interval between the two fixed points, are usually graduated by comparison with a standard thermometer.

Standard ther-
mometer.

The

THERMOME-
TER.

Cases in which
the mercury
need not be
boiled.

The very careful boiling of the mercury, as above described, is absolutely necessary for such thermometers as are to be sealed when full: for if there were any air or moisture left in the bulb, it would prevent the mercury in the tube from descending into the bulb, so that the tube would continue always full. These thermometers are undoubtedly the best; but the vacuum above the mercury does not seem to be an indispensable requisite. If a clean dry tube be filled with pure boiled mercury, and a small bulb be left at the top of the tube, to contain common air, in order that its expansion or condensation, produced by the change in the mercurial surface, may be inconsiderable; there will be few practical objections against such a thermometer; more especially if it be a secondary instrument, graduated by means of a standard. There are some thermometers made with tubes so very small, and bulbs so large in proportion to them, that they will not admit of boiling the mercury in them, but are filled with boiled mercury by means of a condenser. These are necessarily of the kind here mentioned.

Scales of ther-
mometers.
Fahrenheit's.

Reaumur's.

Celsius's.

The thermometers most in use at present are Fahrenheit's, Reaumur's, and Celsius's. In Fahrenheit's scale, the number of degrees between the freezing and boiling water point is 180; the freezing point being at 32°, and the boiling point at 212°, both above 0°, or the part from which the degrees are reckoned both ways. In Reaumur's scale, the number of degrees between these two points is 80, and the freezing point is called 0°, from which the degrees are reckoned both ways. In Celsius's thermometer, the interval

THERMOMETER.



terval is divided into 100° , and the freezing point is called 0° , as in Reaumur's. To reduce these scales THERMOMETERS.
to each other, it must be observed, that one degree of Fahrenheit's is equal to $\frac{4}{5}$ of a degree of Reaumur, Reduction of
degrees of ther-
mometers of
various scales.
and to $\frac{3}{5}$ of a degree of Celsius. Therefore, if the number of degrees of Fahrenheit, reckoned above or below the freezing point, be multiplied by 4, and divided by 9, the quotient will be the corresponding number on Reaumur's scale. Or if the multiplier 5, and the divisor 9, be used, the quotient will give the degrees of Celsius's scale. And, contrariwise, if any number of degrees, either of Reaumur or Celsius, be multiplied by 9, and divided by 4 if of Reaumur, or by 5 if of Celsius, the quotient will give the degrees of Fahrenheit, reckoned either above or below the freezing point, as the case may be.

CHAP. IV.

ON COMBUSTION, AND THE APPLICATION OF HEAT
TO CHEMICAL PURPOSES.APPLICAT.
OF HEAT.Friction; ham-
mering; flint
and steel.

Solar focus.

Chemical mix-
tures.

Combustion.

THE methods of producing an increase of temperature are various. The friction of two pieces of wood, in a turner's lathe, produces heat and flame: a nail may be made red hot by hammering it: and when flint and steel are struck together, small particles of the steel are separated, which are in a strong state of deflagration, and, upon examination with the microscope, are found to have been fused into hollow greyish balls. The sun's light, concentrated by a convex lens, or concave mirror, is likewise found to produce the most astonishing effects, by raising the temperature of bodies. And, among chemical mixtures, there are many by which ignition and flame are produced. In these, and in all instances where the temperature is raised, a diminution of the capacities of the bodies appears to be the effective cause.

Most operations that require an increase of temperature, are performed by the communication of heat from bodies in combustion. The general facts respecting this wonderful process, are the following:— There are certain bodies which, when ignited or heated so as to become luminous, will soon cease to be so, by the loss of that heat which they communicate to the bodies around them: but there are others which,

which, if ignited in contact with the air of the atmosphere, will not lose their ignition, but continue to give out heat, till their volatile parts are dissipated, and the properties of the remainder entirely changed. These last are called combustible bodies. It is found by experiment that the capacities or quantities of heat, in combustible bodies, are not considerable; that the quantity of heat in atmospheric air, in the elastic state, is exceedingly great; and that part of this air is absorbed by bodies in combustion. If, therefore, the temperature of a combustible body be by any means so raised, as that the chemical process by which air becomes condensed and combined with it may go on, the temperature of the air will be raised, as its capacity is diminished, in passing from the elastic to the solid state; and it will therefore give out its heat to the combustible body, which, instead of becoming colder, must increase in temperature, in proportion to the quantity of air condensed in the same time, excepting so far as this effect is diminished by the conducting power of the surrounding bodies.

APPLICAT.
OF HEAT.

Combustion.

The processes which are performed by the simple application of heat, are as follow:

Roasting.—This consists in exposing mineral bodies to the heat of an open fire, for the purpose of dissipating their volatile contents.

Calcination is performed by exposing bodies, in an open vessel, to a strong heat, till no farther change can be produced in them. The body which remains, and withstands the fire, is called a calx. Both these terms are more particularly applied to metals. Such bodies as are very little changed by heat, are called refractory.

D

Fusion

APPLICAT.
OF HEAT.

Fusion.

Fusion consists in heating bodies, in proper vessels, till they become fluid. It is chiefly used for the purpose of uniting smaller bodies into one large mass, and casting them into moulds of any desired figure. The facility with which metals may be united in this way, after they have been divided, is probably the circumstance that induced mankind to use them as the mediums of exchange, or signs of value of all other commodities.

Digestion.

Digestion consists in keeping bodies for a considerable time immersed in a fluid at a higher temperature than that of the atmosphere, in order that combinations may take place that could not else have been effected.

Cementation.

Cementation is a process wherein solid bodies, one or more of them being pulverized, are exposed to heat in proper vessels, with the intention that the more volatile parts of the one body may unite with the other, or with its fixed parts.

Evaporation.

Evaporation consists in the dissipating of fluids by heat.

Concentration.

Concentration consists in increasing the proportion of saline matter in any watery fluid, either by evaporating part of the water, or by causing it to freeze, and taking away the ice.

Distillation.

When evaporation is performed in vessels either perfectly or nearly closed, so that the volatile parts, which are raised in one part of the apparatus, may be received and condensed in the other part, the process is called distillation.

Rectification.

Rectification is a subsequent distillation of the product which comes over.

Sublimation.

In the distillation of such bodies as are solid in the

the usual temperature of the atmosphere, the vapours are scarcely condensed before they become solid. In this case the process is called sublimation; and the condensed vapours, which usually have a powdery form, are called flowers. Such are the flowers of brimstone, of benjamin, of zinc, &c. Solid products, obtained in this way, are called sublimes.

APPLICAT.
OF HEAT.

Some of these operations may be performed by a common culinary fire, and indeed most of them may when the quantities of matter are small, which is usually the case in philosophical experiments. In the arts, where every process requires to be repeatedly carried on in the large way, a variety of furnaces have been contrived, to suit the various intentions of the operators. But experimental inquiries demand the occasional exertion of every branch of chemical operation; for which reason the furnaces and apparatus ought to be constructed on as general principles as possible.

The vessels used in chemistry are—Fig. 1. Crucibles, or pots, made either of earth, black lead, forged iron, or platina. They are used for roasting, calcination, and fusion.

Crucibles. See the plate.

Fig. 2. Cucurbits, matraffes, or bodies, which are glass, earthen, or metallic vessels, usually of the shape of an egg, and open at top. They serve the purposes of digestion, evaporation, &c.

Cucurbits, or matraffes.

Fig. 3. Retorts are globular vessels of earthen ware, glass, or metal, with a neck bended on one side. Some retorts have another neck or opening at their upper part, through which they may be charged; and the opening may be afterwards closed with a stopper. These are called tubulated retorts.

Retorts.

APPLICAT.
OF HEAT.
Receivers.

Fig. 4. Receivers are vessels, usually of glass, of a spherical form, with a straight neck, into which the neck of the retort is usually inserted. When any proper substance is put into a retort, and heated, its volatile parts pass over into the receiver, where they are condensed.

Alembic—of
glass;

Fig. 5. The alembic is used for distillation when the products are too volatile to admit of the use of the last-mentioned apparatus. The alembic consists of a body A, to which is adapted a head B. The head is of a conical figure, and has its external circumference or base depressed lower than its neck; so that the vapours which rise, and are condensed against its sides, run down into the circular channel formed by its depressed part, from whence they are conveyed by the nose or beak C, into the receiver D. This instrument is less simple than the retort, which certainly may be used for the most volatile products, if care be taken to apply a gentle heat on such occasions. But the alembic has its conveniences. In particular, the residues of distillations may be easily cleared out of the body A; and, in experiments of sublimation, the head is very convenient to receive the dry products, while the more volatile and elastic parts pass over into the receiver.

—of metal.

Fig. 6, Is the drawing of an alembic commonly made in metal. The head is contained in a vessel of cold water, to accelerate the condensation; a method which is not so rational as that of cooling the receiver, because the coldness of the head, in the former case, causes much of the vapour to fall again into the body.

Stills for ardent
spirit.

Fig. 7, Represents the large stills used in the distillation of ardent spirits. Instead of using a refrigeratory
or

or receiver, the spirit is made to pass through a spiral pipe, called the worm, which is immersed in a tub of cold water. During its passage it is condensed, and comes out at the lower extremity, E, of the pipe, in a fluid form.

APPLICAT.
OF HEAT.

The best construction of a furnace has not been well ascertained from experience. There are facts which shew that a fire made on a grate near the bottom of a chimney, of equal width throughout, and open both above and below, will produce a more intense heat than any other furnace. What may be the limits for the height of the chimney, is not ascertained from any precise trials; but thirty times its diameter would not probably be too high. It seems to be a disadvantage to contract the diameter of a chimney, so as to make it smaller than that of the fire-place, when no other air is to go up the chimney than what has passed through the fire; and there is no prospect of advantage to be derived from widening it.

Fig. 8, Exhibits the common small furnace for melting. A is the ash-hole, where the air enters. c is the fire-place, containing a covered crucible standing on a support of baked earth, which rests on the grate. D is the passage into E the chimney. At D is a shallow crucible called a cupel, placed in the current of the flame; and at F is an earthen or stone cover, to be occasionally taken off, for the purpose of supplying the fire with fuel.

Melting furnace.

Fig. 9, Is the reverberatory furnace. A is the fire-place, B the dome and chimney, which is moveable. It serves to reflect the flames, and causes them to sur-

Reverberatory furnace.

APPLICAT.
OF HEAT.

Fuel.

round the vessel c, which is by that means more strongly heated than otherwise.

Charcoal is the material most commonly used in furnaces. It produces an intense heat, without smoke; but it is consumed very fast. Coke, or charred pit-coal, produces a very strong and lasting heat. Neither of these produce a strong heat at a distance from the fire. Where the action of flame is required, wood or coal must be burned. Several inconveniencies attend the use of coal, as its fuliginous fumes, and its aptitude to stop the passage of air, by becoming fused. It is used however in the reverberatory furnaces of glass-houses; and is the best material where vessels are to be supplied with a great quantity of heat at no great intensity, such as in distilleries, &c.

Chemical bath.

In many operations where a moderate and regular heat is required, it is advantageous to use a bath, or to coat the vessel intended to be heated. A chemical bath is usually made by putting a quantity of water, sand, or other fluid or pulverulent substance, into a metallic vessel or pot, and immersing the distilling vessel in it. When the water or sand is once heated, it prevents the sudden changes in the intensity of the fire from affecting the vessel that contains the matter under examination. Chemical baths are made with water, sand, iron filings, mercury, and with the fusible composition of eight parts bismuth, five lead, and three tin, which becomes fluid with a less heat than that of boiling water.

Coating.

Coating is chiefly intended to prevent glass vessels from cracking by the sudden variations of heat; and serves likewise to render them capable of preserving their

their figure in higher degrees of heat than they could sustain without it. The materials are clay and fine sand, well worked together into a paste, and with the addition of some hair, such as the bricklayers use. This is laid upon the vessel in successive thin coatings.

APPLICAT.
OF HEAT.

The joints or closures of vessels are made tight by Lutes. compositions called lutes. The clay and sand used for coating make a very good lute. In the distillation of substances which are not corrosive, it is found convenient to close the junctures with paper, or linen, pasted on. Wet strips of bladder may also be used in these cases. Slaked lime and the whites of eggs form a good lute, which speedily dries and becomes firm; but the composition called fat lute is used when the vapours are of a corrosive and volatile nature. This is composed of clay, first made very dry and pulverized, and then beat together into a paste with linseed oil which has been boiled upon litharge, and is known in the shops by the name of drying oil. Fat lute does not harden, but requires to be secured on its place by strips of linen dipped in the lute made of lime and whites of eggs.

The flame of a lamp with many small wicks may be used in distillations that require a low heat.

An ingenious student in chemistry, when he has familiarised himself with the first principles, will soon perceive that there are few philosophical inquiries, if any, that require a large apparatus of furnace, or vessels. A tobacco-pipe is a very useful crucible, in which a great number of operations may be performed in a common fire, especially if urged with a pair of good double bellows. An earthen pot, or iron ladle, will contain a sand-bath; and apothecaries phials, or Florence

Facility of
making ex-
periments.

APPLICAT.
OF HEAT.

flasks, serve very well for mattraffes. Chafing-dishes, or small iron stoves, may be applied to serve many useful purposes. And the blow-pipe and spirit-lamp, with a set of very small retorts and receivers, may be adapted to the performance of almost every part of experimental chemistry.

Moveable furnaces.

The black-lead pots are very convenient for constructing a variety of moveable furnaces. They may be cut without difficulty by a saw whose teeth are set wide; and very easily admit of being scraped, drilled, or ground with sand, to give them the requisite figure. In Dr. Lewis's construction, from whom the four following figures are taken*, the pots which are intended to be applied to each other, are ground flat upon a stone, with a little sand; the holes are sawed with the common compass-saw of the carpenters, and are made a little narrower externally than internally; by which means it is easy to fit them with stoppers made out of the broken pieces, that may be bought where the pots are sold. Three or four hoops of copper-wire, about the thickness of a crow-quill, and first softened by heating it red-hot, are fastened round the pots in the most convenient places, to render them more durable by keeping their parts together, after they may have been cracked. A thin copper hoop serves to secure the place of junction of two pots.

Furnace for open fire.

Fig. 10, Represents a furnace for open fire formed by one pot. The lower square aperture is the door of the ash-pit, and the upper one the door of the fire-place, which, in the intentions this furnace is designed for, is

* Lewis's Philosophical Commerce of Arts.

kept shut. The charcoal is put in at the top, and supplied with air by one or more of the lower apertures; and the intensity of the fire may in some measure be regulated by more or less closing of the apertures. If an iron pot, a ladle, or an old frying-pan, containing sand, be put over this fire on three iron supporters, so as to leave room for the escape of the burned air from the fire, a bath will be formed, in which digestions, Bath. distillations, and other chemical operations, may be performed. The round hole in the bottom serves to insert the nozzle of a pair of bellows, which, when the other apertures are stopped, converts it into a blast furnace.

APPLICAT.
OF HEAT.

Fig. 11, Is a wind furnace, formed by two pots applied mouth to mouth. An iron chimney composed of pieces, by which its length may be regulated so as to increase the draught at pleasure, is put on the top. The crucible containing the subject matters is placed upon a circular piece of brick laid upon the grate, which prevents the cold air from immediately striking the crucible, and endangering the breaking it. The charcoal is put through the fire-place door, or larger aperture of the dome, or upper pot, which should always be closed immediately after each supply of fuel. The two opposite holes in the upper part of the dome afford the conveniency of passing an iron rod through, for safely and commodiously lifting it when intensely heated.

Moveable
wind furnace.

Fig. 12, Is a furnace consisting of two pots, separated by an iron hoop, in which an opening or door is cut. It serves for a reverberatory furnace for distilling with retorts of earthen ware or coated glass. The bottom

Reverberatory
furnace.

APPLICAT. OF HEAT. bottom of the distilling vessel rests on two bars laid across within the lower pot. If the grate of this furnace be occasionally changed for a larger, which may be placed near the edge of the lower pot, a muffle, or small earthen oven, may be placed in the midst of the fire, with its mouth opposite the hole in the iron hoop. In this may be performed all processes that require the admission of air, and frequent inspection, such as assays, enamelling, &c.

Moveable blast
furnace.

Fig. 13, Is an improved blast furnace. The pot which contains the fuel for this purpose, has a number of holes bored at small distances, in spiral lines, all over it, from the bottom up to such an height as it is designed the fuel shall reach. The crucible is placed upon a proper support in the bottom; and the holes are made, not in a perpendicular direction to it, but oblique, that the streams of air forced in through them may but just touch it: by this means the crucible is in no danger of being cracked by the blast, and the impelled heat plays in a kind of spiral upon its surface. The lower pot receives this perforated pot to such a depth that all its holes hang in the cavity; which cavity having no other outlet than the aperture for the bellows, the air blown in through this aperture necessarily distributes itself through the perforations of the inner pot. Both pots may be of the largest size, the external narrow part of the inner falling into the wide mouth of the outer. It wants no addition to its height; but, on the contrary, will be more commodious in regard to the inspection and taking out of the crucible, if all the part above where the fuel reaches be sawed away. The most convenient cover for it, is an iron plate with a round

round hole in the middle, and a handle projecting at one side for lifting it. (Letter A.)

APPLICAT.
OF HEAT.

The force of the fire being thus in a great measure concentrated upon the crucible in the middle of the fuel, the crucible is heated expeditiously, and with a little quantity of fuel, to a very intense degree; while the exterior parts of the furnace are of no great heat, and permit the operator to approach without incommoding him.

Every effect of the most violent heat of furnaces may be produced by the flame of a candle, or lamp, urged upon a small particle of any substance by the blow-pipe. This instrument is sold by the ironmongers; and consists merely of a brass pipe, about one eighth of an inch diameter at one end, and the other tapering to a much less size, with a very small perforation for the wind to escape. The smaller end is bended on one side. For philosophical, or other nice purposes, the blow-pipe is provided with a bowl, or enlargement, B, (fig. 14) in which the vapours of the breath are condensed and detained; and also with three or four small nozzles, with different apertures, to be slipped on the smaller extremity. These are of use when larger or smaller flames are to be occasionally used; because a larger flame requires a larger aperture, in order that the air may effectually urge it upon the matter under examination.

There is an artifice in the blowing through this pipe, which is more difficult to describe than to acquire. The effect intended to be produced is a continual stream of air for many minutes, if necessary, without ceasing. This is done by applying the tongue to the roof of the mouth,

Artifice of
blowing
through the
pipe.

APPLICAT.
OF HEAT.

mouth, so as to interrupt the communication between the mouth and the passage of the nostrils: by which means the operator is at liberty to breathe through the nostrils, at the same time that, by the muscles of the lips, he forces a continual stream of air from the anterior part of the mouth through the blow-pipe. When the mouth begins to be empty, it is replenished by the lungs in an instant; while the tongue is withdrawn from the roof of the mouth, and replaced again in the same manner as in pronouncing the monosyllable tut. In this way the stream may be continued for a long time without any fatigue, if the flame be not urged too impetuously; and even in this case no other fatigue is felt than that of the muscles of the lips.

Flame urged
by the blow-
pipe.

A wax-candle of a moderate size, but thicker wick than they are usually made with, is the most convenient for occasional experiments; but a tallow-candle will do very well. The candle should be snuffed rather short, and the wick turned on one side towards the object, so that a part of it should lie horizontal. The stream of air must be blown along this horizontal part as near as may be without striking the wick. If the flame be ragged and irregular, it is a proof that the hole is not round or smooth; and if the flame have a cavity through it, the aperture of the pipe is too large. When the hole is of a proper figure, and duly proportioned, the flame consists of a neat luminous blue cone, surrounded by another flame of a more faint and indistinct appearance. The strongest heat is at the point of the inner flame.

The subject to
be heated.

The body intended to be acted on by the blow-pipe, ought not to exceed the size of a pepper-corn. It may be laid

laid upon a piece of close-grained well-burned charcoal, unless it be of such a nature as to sink into the pores of that substance, or to have its properties affected by its inflammable quality. Such bodies may be placed in a small spoon made of pure gold, or silver, or platina.

APPLICAT.
OF HEAT.

Many great advantages may be derived from the use of this simple and valuable instrument. Its smallness, which renders it suitable to the pocket, is no inconsiderable recommendation. The most expensive materials, and the minutest specimens of bodies, may be used in these experiments; and the whole process, instead of being carried on in an opaque vessel, is under the eye of the observer from beginning to end. It is true that very little can be determined in this way concerning the quantities of products; but in most cases a knowledge of the contents of any substance is a great acquisition, which is thus obtained in a very short time, and will at all events serve to shew the best and least expensive way of conducting processes with the same matters in the larger way.

The blow-pipe * has deservedly of late years been considered as an essential instrument in a chemical laboratory; and several attempts have been made to facilitate its use by the addition of bellows, or some other equivalent instrument. These are doubtless very convenient, though they render it less portable for mineralogical researches. It will not here be necessary to enter into any description of a pair of double bellows fixed under a table, and communicating with a blow-pipe

—its use rendered easy by bellows.

* See Magellan's edition of Cronstedt's Mineralogy, or Bergmann's Chemical Essays.

which

APPLICAT.
OF HEAT.

which passes through the tube. Smaller bellows, of a portable size for the pocket, have been made for the same purpose. The ingenious chemist will find no great difficulty in adapting a bladder to the blow-pipe, which, under the pressure of a board, may produce a constant stream of air; and may be replenished, as it becomes empty, by blowing into it with bellows, or the mouth, at another aperture furnished with a valve opening inwards.

Blow-pipe
with vital air.

The chief advantage these contrivances have over the common blow-pipe is, that they may be filled with vital or dephlogisticated air, which increases the activity of combustion to an astonishing degree.

C H A P. V.

CONCERNING THE METHODS OF MAKING EXPERI-
MENTS ON BODIES IN THE FLUID AND
IN THE AERIFORM STATE.

FROM the preceding chapter, the methods of conducting processes, in which considerable heat is required, may be easily understood. Little need be said concerning the manner of making experiments with fluid bodies in the common temperature of the atmosphere. Bafons, cups, phials, mattraffes, and other similar vessels, form the whole apparatus required for the purpose of containing the matters intended to be put together; and no other precaution or instruction is required, than to use a vessel of such materials as shall not be corroded or acted upon by its contents, and of sufficient capacity to admit of any sudden expansion, or frothing of the fluid, if expected. This vessel must be placed in a current of air, if noxious fumes arise, in order that these may be blown from the operator.

PROCESSES
WITHOUT
HEAT.

Apparatus for
dense fluids.

The method of making experiments with permanently elastic fluids or air, though simple, is not so obvious. We live immersed in an atmosphere not greatly differing in density from these fluids; which are not, for that reason, sufficiently ponderous to be detained in open vessels by their weight. Their remarkable levity, however, affords a method of confining them, by means of other denser fluids. Dr. Priestley, whose labours have so far exceeded those of his predecessors and contemporaries, both in extent and importance, that he may

— for elastic
fluids.

PROCESSES
WITHOUT
HEAT.

Apparatus for
experiments
with elastic
fluids.

may with justice be styled the father of this important branch of natural philosophy, use the following apparatus.

Fig. 15. A represents a wooden vessel, or tub; K, K, K, is a shelf fixed in the tub. When this apparatus is used, the tub is to be filled with water to such an height, as to rise about one inch above the upper surface of the shelf. B, G, F, are glass jars inverted with their mouths downwards, which rest upon the shelf. If these, or any other vessels open only at one end, be plunged under the water, and inverted after they are filled, they will remain full, notwithstanding their being raised out of the water, provided their mouths be kept immersed; for in this case the water is sustained by the pressure of the atmosphere in the same manner as the mercury in the barometer. It may without difficulty be imagined, that if common air, or any other fluid resembling common air in lightness and elasticity, be suffered to enter these vessels, it will rise to the upper part, and the surface of the water will subside. If a bottle, a cup, or any other vessel in that state which is usually called empty, though really full of air, be plunged into the water with its mouth downwards, scarcely any water will enter, because its entrance is opposed by the elasticity of the included air; but if the vessel be turned up, it immediately fills, and the air rises in one or more bubbles to the surface. Suppose this operation to be performed under one of the jars which are filled with water: the air will ascend as before; but, instead of escaping, it will be detained in the upper part of the jar. In this manner, therefore, we see that air may be emptied out of one vessel into another, by an inverted pouring, in which

which the air is made to ascend from the lower to the upper vessel, in which the experiments are performed, by the action of the weightier fluid, exactly similar to the common pouring of denser fluids, detained in the bottoms of open vessels, by the simple action of gravity. When the receiving vessel has a narrow neck, the air may be poured through a glass funnel, H.

PROCESSES
WITH ELAS-
TIC FLUIDS.

Apparatus for
experiments
with elastic
fluids.

C (fig. 15) is a glass body or bottle, whose bottom is blown very thin, that it may support the heat of a candle suddenly applied, without cracking. In its neck is fitted, by grinding, a tube D, curved nearly in the form of the letter s. This kind of vessel is very useful in various chemical operations, for which it will be convenient to have them of several sizes. In the figure, the body C is represented as containing a fluid, in the act of combining with a substance that gives out air, which passes through the tube into the jar B, under whose mouth the other extremity of the tube is placed. At E is a small retort of glass or earthen ware, whose neck being plunged in the water, beneath the jar F, is supposed to emit the elastic fluid, extricated from the contents of the retort, which is received in the jar.

Body and tube.

When any thing, as a gallipot, is to be supported at a considerable height within a jar, it is convenient to have such wire stands as are represented fig. 16. These answer better than any other, because they take up but little room, and are easily bended to any figure or height.

Stand or sup-
port of wire.

In order to expel air from solid substances by means of heat, a gun-barrel, with the touch-hole screwed up and riveted, may be used instead of an iron retort.

Gun-barrel.

E

The

APPARATUS
FOR ELAS-
TIC FLUIDS

The subject may be put in the chamber of the barrel, and the rest of the bore may be filled with dry sand, that has been well burned, to expel whatever air it might have contained. The stem of a tobacco-pipe, or a small glass tube, being luted in the orifice of the barrel, the other extremity must be put into the fire, that the heat may expel the air from its contents. This air will of course pass through the tube, and may be received under an inverted vessel, in the usual manner.

Phials with
quicksilver.

Burning lens,
or mirror.

But the most accurate method of procuring air from several substances, by means of heat, is, to put them, if they will bear it, into phials full of quicksilver, with the mouths inverted in the same, and then throw the focus of a burning lens or mirror upon them. For this purpose their bottoms should be round, and very thin, that they may not be liable to fly with the sudden application of heat. The body c answers this purpose very well.

Apparatus
with mercury.

Many kinds of air combine with water, and therefore require to be treated in an apparatus in which quicksilver is made use of. This fluid being very ponderous, and of considerable price, it is an object of convenience as well as economy, that the trough and vessels should be smaller than when water is used.

Combustion of
air.

When trial is to be made of any kind of air, whether it be fit for maintaining combustion, the air may be put in a long narrow glass vessel, whose mouth being carefully covered, may be turned upward. A bit of wax candle being then fastened to the end of a wire, which is bended so that the flame of the candle may be upper-

uppermost, is to be let down into the vessel, which must be kept covered till the instant of plunging the lighted candle in the air.

APPARATUS
FOR ELAS-
TIC FLUIDS.

Where the change of dimensions, which follows from the mixture of several kinds of air, is to be ascertained, a graduated narrow cylindrical vessel may be made use of. The graduations may be made by pouring in successive equal measures of water into this vessel, and marking its surface at each addition. The measure may be afterwards used for the different kinds of air; and the change of dimensions will be shewn by the rise or fall of the mercury, or water, in the graduated vessel. The purity of common air being determinable by the diminution produced by the addition of nitrous air, these tubes have been called eudiometer tubes. There are instruments called eudiometers, which consist of an assemblage of parts adapted to the due mixture of these airs, and the accurate measurement of the change of bulk they undergo.

Measuring
tubes.

Eudiometers.

There are some substances, more especially powders, which cannot conveniently be put in a phial, or passed through a fluid. When air is to be extricated from, or added to, these, there is no better method than to place them on a stand under the receiver of the air-pump, and exhaust the common air, instead of excluding it by water or mercury. This process requires a good air-pump and careful management, otherwise the common air will not be well excluded.

Management
of powders.

It is frequently an interesting object to pass the electric spark through different kinds of air, either alone or mixed together. In this case a metallic wire may be fastened in the upper end of a tube, and the sparks,

Electric spark.

APPARATUS
FOR ELAS-
TIC FLUIDS.

Electricity ap-
plied.

Holes drilled in
glass.

Impregnation
of water ;

—with fixed
air.

or shock, may be passed through this wire to the mercury or water used to confine the air. If there be reason to apprehend that an expansion in the air may remove the mercury or water beyond the striking distance, another wire may be thrust up to receive the electricity, or two wires may be cemented into opposite holes in the sides of an hermetically sealed tube. Holes may be made in glass for this and other chemical uses, by a drill of copper, or soft iron, with emery and water ; and, where this instrument is wanting, a small round file with water will cut a notch in small vessels, such as phials or tubes, though with some danger of breaking them. In some electrical experiments of the kind here mentioned, there is reason to expect a fallacious result from the wires being burned by the explosion, or spark. For this reason the electricity may be made to pass through the legs of a syphon, containing the air which is under consideration in the upper part of its curvature. One of the vessels in which the legs of the syphon rest, must therefore be insulated ; and if any watery fluid be used to confine the air, it is generally supposed that no combustion takes place.

The process of impregnating water with any aerial fluid it will combine with, does not require any particular apparatus, but may be performed with such utensils as are every where to be met with. The most usual operation of this kind is that of impregnating water with fixed air ; which may be done in the following manner. The quart bottle c, fig. 17, is filled with water, and inverted into the basin F, which likewise contains a little water. The inversion may be easily

easily managed, without any of the contents of the bottle escaping, if its orifice be covered with a card, to be withdrawn after the immersion. A is a half-pint phial, into which broken pieces of marble or chalk are put; and upon them is poured as much water, rendered very acid by a mixture of oil of vitriol, as may fill the bottle two-thirds. B is a bladder, whose neck is tied fast round a perforated cork of a tapering figure. After the effervescence of the chalk and the acid has begun, the cork is to be thrust into the neck of the phial A, the bladder being previously emptied by pressure. Fixed air will escape from the chalk, and inflate the bladder. When this last is full, it must be disengaged from the bottle, and the bended tube E must be thrust into the orifice of its cork. The aperture of the tube being then placed beneath the mouth of the bottle c, it is easy to discharge the aerial contents of the bladder by pressure into this last. Agitation of the bottle c, without withdrawing its neck out of the water, increases the contact of the air and water, by dividing them into small parts, and by that means causes the absorption to take place in a few seconds. Two or three repetitions of this process impregnate the water so fully, that it will absorb no more in this way. The Pyrmont water is of this kind.

The use of the bladder, in this operation, is only to prevent any of the fluid contents of the bottle A from passing into the bottle c, which would happen in the violent state of ebullition, if the tube E were to pass directly from the bottle A to c. The manipulation is simpler if the bladder have two holes at its opposite

E 3

ends,

APPARATUS FOR ELASTIC FLUIDS. ends, the one containing a cork, constantly kept in the neck of the bottle A, and the other fastened round the tube E, which then remains constantly beneath the mouth of c; and the air is pressed up as occasion may demand. See fig. 18.

Dr. Nooth's apparatus.

When habitual use is made of water impregnated with fixed air, the apparatus of Dr. Nooth is very effectual and convenient. It consists of three glass vessels (fig. 19). The lower vessel c contains the effervescent materials: it has a small orifice at D, stopped with a ground stopper, at which an additional supply of either acid, or water, or chalk, may be occasionally introduced. The middle vessel B is open both above and below. Its inferior neck is fitted by grinding into the neck H of the lower vessel. In the former is a glass valve, formed by two pieces of tube, and a lens, which is moveable, between them, as represented in fig. 20. This valve opens upwards, and suffers the air to pass; but the water cannot return through the tubes, partly because the orifice is capillary, and partly because the flat lens covers the hole. The middle vessel is furnished with a cock E, to draw off its contents. The upper vessel A is fitted, by grinding, into the upper neck of the middle vessel. Its inferior part consists of a tube, that passes almost as low as the centre of the middle vessel. Its upper orifice is closed by a ground stopper F. When this apparatus is to be used, the effervescent materials are put into the lower vessel; the middle vessel is filled with pure water, and put in its place; and the upper vessel is nearly stopped, and likewise put in its place. The consequence is,

that

that the fixed air, passing through the valve at H, ascends into the upper part of the middle vessel B, where, by its elasticity, it re-acts on the water, and forces part up the tube into the vessel A; part of the common air, in this last, being compressed, and the rest escaping by the stopper, which is made of a conical figure, that it may be easily raised. As more fixed air is extricated, more water rises, till at length the water in the middle vessel falls below the lower orifice of the tube. Fixed air then passes through the tube into the upper vessel, and expels more of the common air by raising the stopper. In this situation the water in both vessels, being in contact with a body of fixed air, becomes strongly impregnated with that fluid, after a certain time. This effect may be hastened by taking off the middle and upper vessels together, and agitating them.

APPARATUS
FOR ELAS-
TIC FLUIDS.

Dr. Nooth's apparatus:

The valve is the most defective part of this apparatus: for the capillary tube does not admit the air through, unless there be a considerable quantity condensed in the lower vessel: and the condensation has, in some instances, burst the vessel. —its valve defective.

Modern discoveries, respecting bodies in the aeriform state, have produced several capital improvements in the vessels used for distillation. It was common with the earlier chemists to make a small hole in the upper part of their retorts, that the elastic vapours might escape, which would otherwise have burst the vessels. By this means they lost a very considerable part of their products. Fig. 21, is an apparatus of vessels*, Improvements in distillation.

* Priestley, III.

VESSELS
FOR DISTILL-
ING.

Combination of
receivers.

in which all the products may be examined. A is a matrafs, which communicates with the receiver B, by a tube that reaches very near the bottom of the latter.

The upper part of this receiver communicates in the same manner with the second receiver c, by a tube reaching nearly to the bottom of c. In like manner c communicates with D, and from D proceeds a re-curved tube, which may be inserted beneath an inverted vessel of water, or mercury. It is evident, in this apparatus, that whatever volatile matter escapes from the vessel A, by heat or otherwise, will either be condensed in B, c, or D; and that the aerial products will pass through the whole set, and through the re-curved tube, into the inverted vessel. These receivers may be more or less numerous, according to circumstances; and the volatile products may be condensed in or made to pass through, water, oil, or any other fluids placed in either of the receivers. The tubes may be either fitted in with cork and cement; or, which is better, but more expensive, by grinding. Small vessels of this kind form a convenient interruption in the recurved tube, passing from a bottle containing matters that give out air, as they are preferable in closeness and neatness to a bladder.

Improved re-
ceiver.

Fig. 22, Exhibits an improvement in the receiver in distillation*. A is the retort. B an intermediate vessel, called an adopter, which is only occasionally used, c the receiver, having two necks; one at D, inserted into a bottle which receives the products which are

* By Mr. Woulfe. Priestley, III.

usually

usually condensed in the receiver; and the other, at *E*, ^{VESSELS} transmits the more volatile or aeriform products into a ^{FOR DISTILL-} ^{ING.} basin *G*, containing water; beneath the surface of which the extremity of the neck *E* is plunged. It is obvious that this apparatus is more particularly useful when the products are such as combine with the fluids in *G*, and would otherwise escape; and it is hardly necessary to observe, that a bottle, or other convenient vessel, may be substituted instead of the basin *G*.

It often happens in chemical processes, from the irregularity of the heat, or from other circumstances, that the condensation is more rapid, in proportion to the supply of vapour, at some periods of the same operation than at others. Whenever this takes place, the elasticity of the vapours will not be equal to the external pressure of the air; and if any orifice of the vessels, which are in other respects closed, be plunged in water, or any other fluid, this last will be pressed into the vessels. The remedy for this inconvenience is, to plunge the neck of the vessel to no greater depth in the water, than that the fall of the water, in the receiving vessel, may leave the orifice open for the admission of air, before the water has risen high enough above the orifice to reach the contents of the vessels. This effect is increased by making the neck large, in proportion to the diameter of the vessel which contains the water. Thus, if the neck *E* be made large, and the water from the basin *G* should, by a rapid condensation in *c*, be forced up the neck, the surface of the water in *G* will fall so much as to leave the lower orifice of *E* uncovered, before any considerable rise can take

Remedy against
absorption.

DISTILLATION. take place; but if F were narrower, its whole capacity would be filled, and the water would run over into c before the fall in G would be sufficient to uncover the orifice of F, and restore the equilibrium, by admitting common air. This observation applies to all chemical vessels, and is in no case more essential than when the neck of a simple retort is plunged in water contained in a receiver.

Remedy against
absorption:

The above contrivance, which is Mr. Babington's, cannot very conveniently be applied to the apparatus fig. 21, in which nevertheless the condensation of elastic matter in the retort might occasion a disagreeable return of the fluids from the respective bottles in succession. Chaptal remedies this by a very simple expedient. He has the tube of communication between A and B rather too short to reach the liquid in B; and through the bottom or upper part of this inverted receiver B he passes a small tube open at both ends, and plunged into the liquid. This communication with the external air has no perceptible effect, as far as relates to any escape of the vapours; though it effectually remedies the consequences of absorption.

—of Chaptal.

C H A P. VI.

CONCERNING THE BALANCE AND WEIGHTS, WITH
A COMPARATIVE TABLE OF THE VARIOUS
WEIGHTS MADE USE OF IN EUROPE.

THE beginning and end of every exact chemical process consist in weighing. With imperfect instruments this operation will be tedious and inaccurate: but, with a good balance, the results will be satisfactory; and much time, which is so precious in experimental researches, will be saved. I have not, therefore, thought it improper to devote a whole chapter to this general and important subject; by the help of which, if attentively considered, the chemical student may learn to distinguish a good instrument, or correct the errors of a bad one.

THE
BALANCE.

The balance is a lever, whose axis of motion is formed with an edge like that of a knife; and the two dishes at its extremities are hung upon edges of the same kind. These edges are first made sharp, and then rounded with a fine hone, or a piece of buff leather. The excellence of the instrument depends, in a great measure, on the regular form of this rounded part. When the lever is considered as a mere line, the two outer edges are called points of suspension, and the inner the fulcrum. The points of suspension are supposed to be at equal distances from the fulcrum, and to be pressed with equal weights when loaded.

Balance described.

Points of suspension.

Fulcrum.

1. If

THE
BALANCE.
Propositions.

1. If the fulcrum be placed in the center of gravity of the beam, and the three edges lie all in the same right line, the balance will have no tendency to one position more than another; but will rest in any position it may be placed in, whether the scales be on or off, empty or loaded.

2. If the center of gravity of the beam, when level, be immediately above the fulcrum, it will overset by the smallest action; that is, the end which is lowest will descend: and it will do this with more swiftness the higher the center of gravity, and the less the points of suspension are loaded.

3. But if the center of gravity of the beam be immediately below the fulcrum, the beam will not rest in any position but when level; and, if disturbed from that position, and then left at liberty, it will vibrate, and at last come to rest on the level. Its vibrations will be quicker, and its horizontal tendency stronger, the lower the center of gravity, and the less the weight upon the points of suspension.

4. If the fulcrum be below the line joining the points of suspension, and these be loaded, the beam will overset, unless prevented by the weight of the beam tending to produce an horizontal position; as in § 3. In this last case, small weights will equilibrate, as in § 3; a certain exact weight will rest in any position of the beam, as in § 1; and all greater weights will cause the beam to overset, as in § 2. Money scales are often made this way, and will overset with any considerable load.

Money scales.

5. If the fulcrum be above the line joining the points of suspension, the beam will come to the horizontal

zontal position, unless prevented by its own weight, as in § 2. If the center of gravity of the beam be nearly in the fulcrum, all the vibrations of the loaded beam will be made in times nearly equal, unless the weights be very small, when they will be slower. The vibrations of balances are quicker, and the horizontal tendency stronger, the higher the fulcrum.

THE
BALANCE.

Propositions.

6. If the arms of a balance be unequal, the weights in equipoise will be unequal in the same proportion. It is a severe check upon a workman to keep the arms equal, while he is making the other adjustments in a strong and inflexible beam.

7. The equality of the arms of a balance is of use, in scientific pursuits, chiefly in the making of weights by bisection. A balance with unequal arms will weigh as accurately as another of the same workmanship with equal arms, provided the standard weight itself be first counterpoised, then taken out of the scale, and the thing to be weighed be put into the scale, and adjusted against the counterpoise. Or, when proportional quantities only are considered, as in chemical and other philosophical experiments, the bodies and products under examination may be weighed against the weights, taking care always to put the weights in the same scale. For then, though the bodies may not be really equal to the weights, yet their proportions amongst each other will be the same as if they had been accurately so.

Weighing with
a balance which
is not equilibra-
chial.

8. But though the equality of the arms may be well dispensed with, yet it is indispensably necessary that their relative lengths, whatever they may be, should continue invariable. For this purpose, it is necessary
either

THE
BALANCE.

either that the three edges be all truly parallel, or that the points of suspension and support should be always in the same part of the edge. This last requisite is the most easily obtained.

Construction.

The balances made in London are usually constructed in such a manner, that the bearing parts form notches in the other parts of the edges; so that the scales being set to vibrate, all the parts naturally fall into the same bearing. The balances made in the country have the fulcrum edge straight, and confined to one constant bearing by two side plates. But the points of suspension are referred to notches in the edges, like the London balances. The balances here mentioned, which come from the country, are inclosed in a small iron japanned box; and are to be met with at the Birmingham and Sheffield warehouses, though less frequently than some years ago; because a pocket contrivance for weighing guineas and half guineas has got possession of the market. They are, in general, well made and adjusted, turn with the twentieth of a grain when empty, and will sensibly shew the tenth of a grain, with an ounce in each scale. Their price is from five shillings to half-a-guinea; but those which are under seven shillings have not their edges hardened, and consequently are not durable. This may be ascertained by the purchaser, by passing the point of a penknife across the small piece which goes through one of the end boxes; if it makes any mark or impression, the part is soft.

The turn.

9. If a beam be adjusted so as to have no tendency to any one position, as in § 1, and the scales be equally loaded; then, if a small weight be added in one of the scales,

scales, that balance will turn, and the points of suspension will move with an accelerated motion, similar to that of falling bodies; but as much slower in proportion, very nearly, as the added weight is less than the whole weight borne by the fulcrum.

THE
BALANCE.
Propositions.

10. The stronger the tendency to an horizontal position in any balance, or the quicker its vibrations, §§ 3, 5, the greater additional weight will be required to cause it to turn or incline to any given angle. No balance therefore can turn so quick as the motion deduced in § 9. Such a balance as is there described, if it were to turn with the ten thousandth part of the weight, would move at quickest ten thousand times slower than a falling body; that is, the dish containing the weight, instead of falling through sixteen feet in a second of time, would fall through only two hundredth parts of an inch, and it would require four seconds to move through one third part of an inch: consequently, all accurate weighing must be slow. If the indexes of two balances be of equal lengths, that index which is connected with the shorter balance will move proportionally quicker than the other. Long beams are the most in request, because they are thought to have less friction. This is doubtful: but the quicker angular motion, greater strength, and less weight, of a short balance, are certain advantages.

Accurate
weighing is
slow.

Long beams.

11. Very delicate balances are not only useful in nice experiments, but are likewise much more expeditious than others in common weighing. If a pair of scales, with a certain load, be barely sensible to the one-tenth of a grain, it will require a considerable time to ascertain the weight to that degree of accuracy,
because

THE
BALANCE.
Propositions.

because the turn must be observed several times over, and is very small. But if no greater accuracy were required, and scales were used which would turn with the hundredth of a grain, a tenth of a grain more or less would make so great a difference in the turn, that it would be seen immediately.

12. If a balance be found to turn with a certain addition, and is not moved by any smaller weight, a greater sensibility may be given to that balance, by producing a tremulous motion in its parts. Thus, if the edge of a blunt saw, a file, or other similar instrument, be drawn along any part of the case or support of a balance, it will produce a jarring, which will diminish the friction on the moving parts so much, that the turn will be evident with one third or one fourth of the addition that would else have been required. In this way a beam which would barely turn by the addition of the tenth of a grain, will turn with the thirtieth or fortieth of a grain.

13. A balance whose horizontal tendency depends only on its own weight, as in § 3, will turn with the same addition, whatever may be the load: except so far as a greater load will produce a greater friction.

14. But a balance whose horizontal tendency depends only on the elevation of the fulcrum, as in § 5, will be less sensible the greater the load; and the addition requisite to produce an equal turn will be in proportion to the load itself.

15. In order to regulate the horizontal tendency in some beams, the fulcrum is placed below the points of suspension, as in § 4, and a sliding weight is put upon the cock or index; by means of which the centre of gravity

gravity may be raised or depressed. This is an useful contrivance.

THE
BALANCE.

16. Weights are made by a subdivision of a standard weight. If the weight be continually halved, it will produce the common pile, which is the smallest possible number for weighing between its extremes, without placing any weight in the scale with the body under examination. Granulated lead is a very convenient substance to be used in this operation of halving, which however is very tedious. The readiest way to subdivide small weights, consists in weighing a certain quantity of small wire, and afterwards cutting it into such parts, by measure, as are desired. Or the wire may be wrapped close round two pins, and then cut asunder with a knife. By this means it will be divided into a great number of equal lengths, or small rings. The wire ought to be so thin, as that one of these rings may barely produce a sensible effect on the beam. If any quantity (as, for example, a grain) of these rings be weighed, and the number then reckoned, the grain may be subdivided in any proportion, by dividing that number, and making the weights equal to as many of the rings as the quotient of the division denotes. Then, if 750 of the rings amounted to a grain, and it were required to divide the grain decimally, downwards, $\frac{9}{10}$ would be equal to 675 rings, $\frac{8}{10}$ would be equal to 600 rings, $\frac{7}{10}$ to 525 rings, &c. Small weights may be made of thin leaf brass. Jewellers foil is a good material for weights below the $\frac{1}{10}$ of a grain, as low as to the $\frac{1}{100}$ of a grain; and all lower quantities may be either estimated by the position of the index, or shewn by actually counting

Sets of weights.

Common pile.

Bisection.

Wire rings.

F

ing

THE
BALANCE.

Number of
weights re-
quired to form
a set.

ing the rings of wire, whose value has been determined.

17. In philosophical experiments, it will be found very convenient to admit no more than one dimension of weight. The grain is of that magnitude as to deserve the preference. With regard to the number of weights the chemist ought to be provided with, writers have differed according to their habits and views. Mathematicians have computed the least possible number with which all weights, within certain limits, might be ascertained; but their determination is of little use, because, with so small a number, it must often happen, that the scales will be heavily loaded with weights, on each side, put in with a view only to determine the difference between them. It is not the least possible number of weights which it is necessary an operator should buy to effect his purpose, that we ought to enquire after, but the most convenient number for obtaining the results with accuracy and expedition. The error of adjustment is the least possible, when only one weight is in the scale; that is, a single weight of five grains is twice as likely to be true, as two weights, one of three, and the other of two grains, put into the dish to supply the place of the single five, because each of these last has its own probability of error in adjustment. But, since it is as inconsistent with convenience to provide a single weight, as it would be to have a single character for every number; and as we have nine characters, which we use in rotation, to express higher values according to their position; it will be found very serviceable to make the set of weights correspond with our numerical system.

system. This directs us to the set of weights, as follows: 1000 grains, 900 g. 800 g. 700 g. 600 g. 500 g. 400 g. 300 g. 200 g. 100 g. 90 g. 80 g. 70 g. 60 g. 50 g. 40 g. 30 g. 20 g. 10 g. 9 g. 8 g. 7 g. 6 g. 5 g. 4 g. 3 g. 2 g. 1 g. $\frac{2}{10}$ g. $\frac{3}{10}$ g. $\frac{7}{10}$ g. $\frac{6}{10}$ g. $\frac{5}{10}$ g. $\frac{4}{10}$ g. $\frac{3}{10}$ g. $\frac{2}{10}$ g. $\frac{1}{10}$ g. $\frac{2}{100}$ g. $\frac{3}{100}$ g. $\frac{7}{100}$ g. $\frac{6}{100}$ g. $\frac{5}{100}$ g. $\frac{4}{100}$ g. $\frac{3}{100}$ g. $\frac{2}{100}$ g. $\frac{1}{100}$ g. With these the philosopher will always have the same number of weights in his scales as there are figures in the number expressing the weights in grains.

THE
BALANCE.

Decimal set of
weights.

Thus 742.5 grains will be weighed by the weights 700, 40, 2, and $\frac{5}{10}$.

I shall conclude this chapter with an account of some balances I have seen or heard of, and annex a table of the correspondence of weights of different countries.

Muschenbroek, in his *Cours de Physique* (French translation, Paris, 1769), tom. ii. p. 247, says, he used an ocular balance of great accuracy, which turned (trebuchoit) with $\frac{1}{40}$ of a grain. The substances he weighed were between 200 and 300 grains. His balance, therefore, weighed to the $\frac{1}{12000}$ part of the whole; and would ascertain such weights truly to four places of figures.

The balance of
Muschen-
broek :

In the *Philosophical Transactions*, vol. lxvi. p. 509, — of Bolton. mention is made of two accurate balances of Mr. Bolton; and it is said that one would weigh a pound, and turn with $\frac{1}{10}$ of a grain. This, if the pound be avoirdupois, is $\frac{1}{70000}$ of the weight; and shews that the balance could be well depended on to four places of figures, and probably to five. The other weighed

F2

half

THE half an ounce, and turned with the $\frac{1}{100}$ of a grain.
BALANCE. This is the $\frac{1}{34000}$ of the weight.

Balance of Mr. Read: In the same volume, p. 511, a balance of Mr. Read's is mentioned, which readily turned with less than one pennyweight, when loaded with 55 pounds, before the Royal Society; but very distinctly turned with four grains when tried more patiently. This is about the $\frac{1}{28000}$ part of the weight; and therefore this balance may be depended on to five places of figures.

—of Mr.
Whitehurst:

Also, p. 576, a balance of Mr. Whitehurst's weighs one pennyweight, and is sensibly affected with the $\frac{1}{2000}$ of a grain. This is $\frac{1}{48000}$ part of the weight.

—of the
Author:

I have a pair of scales of the common construction, § 8, made expressly for me by a skilful workman in London. With 1200 grains in each scale, it turns with $\frac{1}{70}$ of a grain. This is the $\frac{1}{84000}$ of the whole; and therefore about this weight may be known to five places of figures. The proportional delicacy is less in greater weights. The beam will bear near a pound troy, and when the scales are empty it is affected by the $\frac{1}{10000}$ of a grain. On the whole, it may be usefully applied to determine all weights between 100 grains and 4000 grains to four places of figures.

—of Mr. Al-
chorne:

A balance belonging to Mr. Alchorne, of the Mint, in London, is mentioned, vol. lxxvii. p. 205, of the Philosophical Transactions. It is true to 3 grains with 15 lb. an end. If these were avoirdupois pounds, the weight is known to $\frac{1}{33000}$ part, or to four places of figures, or barely five.

—of Dr. Geo.
Fordyce.

A balance (made by Ramsden, and turning on points instead of edges) in the possession of Dr. George Fordyce,

dyce, is mentioned in the lxxvth volume of the Philosophical Transactions. With a load of four or five ounces, a difference of one division in the index was made by the $\frac{1}{10000}$ of a grain. This is $\frac{1}{3840000}$ part of the weight; and, consequently, this beam will ascertain such weights to five places of figures, besides an estimated figure.

THE
BALANCE.

I have seen a strong balance in the possession of my friend Mr. Magellan, of the kind mentioned in § 15, which would bear several pounds, and shewed $\frac{1}{10}$ grain, with one pound an end. This is the $\frac{1}{700000}$ of the weight, and answers to five figures. But I think it would have done more by a more patient trial than I had time to make.

The balance of
Mr. Magellan :

The Royal Society's balance, which was lately made by Ramsden, turns on steel edges upon planes of polished crystal. I was assured that it ascertained a weight to the seven millionth part. I was not present at this trial, which must have required great care and patience, as the point of suspension could not have moved over much more than $\frac{2}{1000}$ of an inch in the first half minute; but, from some trials which I saw, I think it probable that it may be used in general practice to determine weights to five places and better.

—of the Royal
Society.

From this account of balances the young student may form a proper estimate of the value of those tables of specific gravities, which are carried to five, six, and even seven places of figures, and likewise of the theoretical deductions in chemistry that depend on a supposed accuracy in weighing, which practice does not authorise. In general, where weights are given to five places of figures, the last figure is an estimate

Inferences.

THE
BALANCE.

or guess figure; and where they are carried farther, it may be taken for granted that the author deceives either intentionally, or from want of skill in reducing his weights to fractional expressions, or otherwise.

Comparison of
Weights :

—by Monf.
Tillet.

Among the numerous public exertions which our learned neighbours, the French, have made in favour of the sciences, the determination of the relative proportions of the weights used in various parts of Europe, is by no means one of the least. The most exact standard weights were procured by means of the ambassadors of France, resident in the various places; and these were compared by Monf. Tillet with the standard mark in the pile called the *poids de Charlemagne*, preserved in the Cour de Monnoies at Paris. His experiments were made with an exact balance made to weigh one mark, and sensible to one quarter of a grain. Now, as the mark contains 18,432 quarter grains, it follows that his balance was a good one, and would exhibit proportions to four places, and a guess figure. The results are contained in Table II. (Appendix), extracted from Monf. Tillet's excellent Paper in the *Memoirs of the Royal Academy of Sciences* for the year 1767. I have added the two last columns, which shew the number of French and English grains contained in the compound quantities against which they stand. The English grains are computed to one-tenth of a grain, though the accuracy of weighing came no nearer than about two-tenths.

C H A P. VII.

ON THE ATTRACTIONS EXERTED BETWEEN BODIES;
 PARTICULARLY THOSE WHICH THE
 CHEMISTS CALL ELECTIVE
 ATTRACTIONS.

THUS far we have attended chiefly to the changes AFFECTIONS
OF BODIES.
 produced in bodies by an alteration in their tem-
 perature, and to the methods of conducting chemical
 operations. We now proceed to consider those actions
 which take place between the parts of bodies of diffe-
 rent kinds. These form a branch of knowledge of the Great import-
ance of the
knowledge of
the actions be-
tween the
parts of bodies.
 greatest importance, but of such an extended nature
 as to require the utmost caution to avoid error in en-
 deavouring to acquire it. The whole scientific part of
 chemistry depends on a right interpretation of facts of
 this kind. In the investigation of those general truths
 which may be considered as laws of nature, we cannot
 therefore be too careful in distinguishing well-established
 facts from the ingenious though inadequate conclusions
 which theoretical writers are too ready to form.

That property of matter or body by which we think Inertia of mat-
ter.
 we can best determine its quantity, is its inertia, or the
 resistance it makes to the communication of motion.
 We cannot perhaps form any idea why there should be
 more difficulty in moving one body than another, ex-
 cept that it really consists of a larger portion of matter.
 The perceptible extension of the same body will vary, Extension.

ATTRAC-
TIONS.

Gravity may
perhaps be mo-
dified ;

if the dimensions of its pores be either increased or diminished ; and there is no inconsistency in supposing it at least possible that its weight, or the force by which it is urged towards the earth, may not in all cases continue unaltered, but be capable of modification like the attractions of magnetism and electricity. Neither the extension nor the weight of bodies appears therefore to be original measures of their quantities of matter ; how far they may be used as such, must depend on their coincidence with the inertia.

—but is not
found to vary
in experiments.

After a proper allowance has been made for the effects of the earth's rotation on its axis, it is found that the power of gravitation, in giving motion to the balls of pendulums, is accurately in proportion to their masses, as measured by their resistance or inertia. The weights of bodies therefore are measures of their quantities of matter ; and though the forces with which various bodies of equal magnitude are urged towards the earth, are different, we do not suppose the attraction or affinity between those bodies and the earth to be stronger or weaker in the several instances, but only that the masses are greater or less. Thus, though a cubic inch of gold weighs more than twice as much as a cubic inch of copper, we do not suppose a stronger attraction between gold and the earth ; but conclude that one general force acts on both, whose effects are greater on the former body than the latter, because the mass of the former is really greater than that of the latter.

Usual inference.

Effects of attraction :

—cohesive.

The effects of attraction between one body and another are so numerous, that we cannot avoid perceiving them every moment. Two smooth polished pieces of metal

metal adhere when pressed together. Water and other fluids take the form of globules, and will stick to various bodies, and pass into the pores of sponge, bread, or the cavities of small tubes. Solid bodies retain their form by the adhesion of their parts; and without this power it is impossible to conceive how the universe could, for a moment, subsist in its present form.

ATTRAC-
TIONS.

It may be questioned whether this cohesive attraction be the same power as gravity. To decide the enquiry, it will be necessary to compare their manner of action. The force of gravity acts in the inverse proportion of the square of the distance between the bodies: but the effects of cohesion are found to increase at a much faster rate, as the bodies approach; so that its power is incomparably greatest at small distances. This seems to be a sufficient reason for considering gravitation and cohesion as two distinct powers.

Cohesive at-
traction differs
from gravity.

The elective attraction of the chemists—such, for example, as when copper, being dissolved in an acid, is separated, and falls to the bottom in a powdery form, on the addition of iron—may, in all its numerous varieties, be either one general power, acting like gravity, according to the masses or densities of the particles; or it may, like magnetism, be dependent more on the peculiar qualities of those particles than on their masses. If the former were the case, we might simplify our deductions by admitting that cohesion and elective attraction are the same thing. It will be easy to examine whether this position will, in any one instance, lead us into an error; and, if it does, it must be abandoned. Spirit of wine dissolves resin; water does not: hence it will follow, if the attraction depend on the density of particles,

Elective attrac-
tion.

Question.

**CHEMICAL
ATTRAC-
TIONS.**

Elective attrac-
tion does not
depend on den-
sity.

ticles, that the particles of spirit of wine are denser than those of water. But, again, water dissolves gums; spirit does not: whence, by the same reasoning, we should deduce, that the particles of water are densest. But the true inference is, that if these different effects depend on any general law, it does not follow the density of the particles; and till that general law is discovered, we ought to consider the various attractions which occur in chemistry, as peculiar to the bodies in which they are observed.

—probably on
figure.

Bergman, Morveau, and other eminent chemists, are inclined to the opinion that there is but one general power of attraction in nature, which is modified chiefly by the figure of particles when extremely near each other. But this has not been strictly examined.

Aggregation.

The adhesion of parts of the same kind, is called aggregation. Thus, a number of pieces of brimstone united by fusion, form an aggregate. The union of bodies of different kinds, in a gross way, is called mixture. Thus sand and salt of tartar may be mixed together. But when the very minute parts of one body unite with those of another so intimately as to form a body which has properties different from those

Combination,
or composition.

of either of them, the union is called combination, or composition. For example, sand and salt of tartar, exposed to a strong heat, combine, and form a compound called glass. The minutest parts into which an aggregate can be imagined to be divided without decomposition, are called integrant parts; but the parts into which it is divided by decomposition, are called component parts or principles.

Integrant and
component
parts.

Principles

Principles which cannot be subdivided by art, are called elements, or first principles; and the principles made up of these, are called secondary principles. Some writers carry this order still farther; but it must be confessed that no means have yet been devised to shew unequivocally whether any such subordination of principles exists. We may indeed discover the component parts of bodies; but we know nothing of their arrangement,

CHEMICAL,
ATTRAC-
TIONS.

Elements, or
first principles,

As the chemical attractions, like other powers of the same kind, are weaker, the greater the distance between the parts which act on each other; and as heat enlarges the dimensions of the bodies; doubtless, by separating their parts, it will not be difficult to explain the effect of heat upon the changes produced in bodies by their elective attractions. Heat.
See pag. 2, 3.

If two solid bodies, disposed to combine together, be brought into contact with each other, the particles that touch will combine, and form a compound; and the process will go no further, if the compound still retain the solid form. But if the compound be of such a nature as to have its point of congelation or solidity much lower than the temperature in which the experiment is made, or if it attract water from the atmosphere, it will be fluid; and the essential property of a fluid being, that all its particles may freely move amongst each other, the parts of each body will be at liberty to move in succession, so as best to obey the elective attraction. The consequence will be, that a new compound, in a fluid form, will be produced by the union of the two bodies. An instance of this has already been shewn in the mixture of ice and salt. Simple combination.
Page 19.

If one of the two bodies be fluid at the temperature of

Suspension.
of

CHEMICAL
ATTRAC-
TIONS.

Solvent, or
menstruum.

of the experiment, its parts will successively unite with the parts of the solid, which will by that means be suspended in the fluid, and disappear. Such a fluid is called a solvent, or menstruum, and the solid body is said to be dissolved. Thus water dissolves salt, mercury dissolves gold, glass of lead dissolves sand, &c.

Water.

In the humid way, where the fluid state is produced by means of water, and in many cases of which the dissolved bodies may be recovered by evaporating the water, it is usual to attend only to the actions of the suspended bodies, and neglect the fluid, because common to all experiments of this kind. But as the water certainly has as great a share in modifying the effect which follows, as any other of the bodies present, the elective attractions between bodies held in solution in water, will not in general be the same as when the menstruum is spirit, oil, or æther; or when, in the dry way, one of the bodies is rendered fluid by strong heat.

Cause of error
in estimating
the attractions.

Limits of satu-
ration :

in fluids :

Some substances unite in all proportions. Such, for example, are acids in general, and some other salts, with water; and many of the metals with each other. But there are likewise many substances which cannot be dissolved in a fluid, at a settled temperature, in any quantity beyond a certain proportion. Thus water will dissolve only about one fourth of its weight of common salt; and if more be added, it will remain solid. A fluid which holds in solution as much of any substance as it can dissolve, is said to be saturated with it. But saturation with one substance does not deprive the fluid of its power of acting on and dissolving some other bodies, but in many cases increases that

that power. For example, water, saturated with salt, will dissolve sugar; and water, saturated with fixed air, will dissolve iron, though, without that addition, its action on that metal is scarcely perceptible. The word saturation is likewise used in another sense by chemists: —in general, the union of two principles produces a body whose properties are different from those of its component parts, but which resemble those of the predominating principle. When the principles are in such proportion as that neither may predominate, they are said to be saturated with each other; but if otherwise, the most predominant principle is said to be under-saturated, and the other over-saturated.

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ATTRAC-
TIONS.

Fluids in general dissolve a greater quantity of any substance the higher the temperature. This probably arises from the fluidity of the body in solution being promoted by the heat.

Solution assisted
by heat.

When two bodies, which would not otherwise combine, are made to unite by the addition of a third, the latter is called a medium. Thus the iron and water, in the instance lately mentioned, are said to have combined by the medium of fixed air.

Medium of
combination.

It often happens, on the contrary, that the tendency to combination between a solvent and another body, is weakened or destroyed by the addition of a third. Thus spirit of wine weakens the action of water upon most salts, and of course separates them from it. If to a saturated solution of nitre in water there be added an equal measure of strong ardent spirit, the nitre becomes solid, and falls down in an instant to the bottom of the phial. The substance thrown down from a solvent by the addition of any other matter, is said to

Separation, or
precipitation.

CHEMICAL be precipitated, and many such products are called
ATTRAC- precipitates.
TIONS.

Simple elective
attraction.

When a compound of two principles is so affected by the addition of a third, that a new compound is formed of this last principle and one of the other two; at the same time that the principle which was part of the original compound, but does not enter into the second combination, is disengaged; the decomposition and new combination are said to be produced by simple elective attraction or affinity.

Examples of
simple elective
attraction:

—in the humid
way:

Most operations of nature or art are so complex, that it is exceedingly difficult to exemplify these effects. The following instance will exhibit an effect of simple elective attraction, if we overlook the effect of the water, which is present in both salts. Common salt consists of two principles. The one is the mineral alkali commonly known by the name of salt of soda; and the other is the marine acid, which, when combined with water, is known by the name of spirit of salt. If the vitriolic acid be poured upon common salt, it will attract the alkali more strongly than it is attracted by the marine acid. The consequence will be, that it will unite with the alkali, and form a new compound, called Glauber's salt, while the marine acid flies off in the form of air. This air, meeting with moisture in the atmosphere, combines with it, and forms the common marine acid visible in the form of white fumes.

—in the dry
way.

In the dry way: If a combination of lead and sulphur be fused with iron, the sulphur unites with this last, and leaves the lead free.

If we were to speculate on these events, it would
be

be easy to shew from what supposed action among the particles they may happen. If a particle of alkali be surrounded by particles of marine acid, and the vitriolic acid be added, the particles of these last may be so strongly attracted by the alkali as to approach it, and remove the particles of marine acid beyond the limit of sensible attraction. This effect may be facilitated by the action of heat, which increases the distances between parts of bodies; and the disengaged substance may assume either the solid, fluid, vaporous, or aerial state, according to the temperature and the peculiar properties of the body itself in that respect.

CHEMICAL
ATTRAC-
TIONS.

Where two bodies, each consisting of two principles, are so disposed as to act on each other, and the order of the principles changes in such a manner as to form two other bodies composed of different principles, the change is said to be produced by double affinity, or double elective attraction.

In the humid way: Let mercury be dissolved in the nitrous acid (or spirit of nitre of the shops) until the acid will take up no more. The solution will then consist of a mercurial salt dissolved in water. Let tartar, which is a salt consisting of a peculiar acid united with the vegetable alkali, be added. The consequence will be, that the alkali of the tartar will quit its own acid, and, uniting with the nitrous acid, will form nitre, which will continue dissolved; and, on the other hand, the acid of the tartar, being disengaged, will unite itself to the mercury, and form a salt, which, on account of its insolubility, will fall down in the form of a powder.

Example: in
the humid way:

In the dry way: If an alloy of gold and copper be —dry way.
fused

CHEMICAL
ATTRAC-
TIONS.

fused with the antimony of the shops, which consists of sulphur and a metallic body called regulus of antimony, the sulphur will unite with the copper, and float above, while the gold and the regulus combine together, and occupy the lower part of the crucible.

Numerical expression of affinity.

One of the principal objects of chemical research consists in the numerical expression of the attractive powers of bodies. If this were well ascertained, it is probable we should be able to foretel, not only the effects of simple or double affinity, but likewise in what cases the compounds of three or more substances take place. See Appendix.

Mechanical properties of bodies do not follow the properties of their component parts.

No regular connection has been yet discovered between the solubility in water, the fusibility, volatility, specific gravity, and other obvious properties of the component parts of bodies, and of the compounds they produce. Hence it happens, in humid operations, that the insoluble products will either fall to the bottom, or rise to the surface, according to their weights. In some processes, all the products will be thus separated; and in others the whole will remain dissolved. In the dry way likewise some products will rise, others will become fluid, and others fixed, so as to require a stronger heat to fuse them than before.

Utility of these changes.

These several changes afford means to the chemist of separating bodies from each other. When two different kinds of salt are dissolved in water, it would be almost impossible to separate them if they were both equally soluble; because evaporation would leave both in a confused mass. But where the one is more soluble than the other, the latter will begin to be separated, and may be taken out at a period of the evaporation, at which

which the whole of the former will remain suspended. So likewise the advantages derived from the processes of distillation, sublimation, and other dry operations, are founded on these different properties of bodies.

CHEMICAL
ATTRAC-
TIONS.

The parts of all bodies which take the solid state are disposed to arrange themselves in such a manner as to produce some regular geometrical figure in the solid. Thus ice, during its formation in water, or even in the open air, always assumes a regular figure, as far as circumstances will permit. The same is observable in the fixation of other fluids, and also in the separation of bodies from their solvents, as salts from water. This property is called crystallization, and the regularly-figured bodies are called crystals. The figure of crystals is influenced by so many circumstances—such as the quickness of their formation, the temperature and agitation of the fluid, the presence of light, and others—that little dependence can be placed on it as an indication of the composition of bodies; though the experienced operator will doubtless derive some advantage by attending to it.

The regular arrangement of parts in crystallization is supposed by some to be the consequence of a property in the particles of bodies, similar to polarity in magnetism. And indeed it seems reasonable to infer, that two compounded particles, coming together by attraction, undisturbed by any other cause, should dispose themselves so as to apply such sides of each together, as are occupied by principles the most attractive of each other.

Polarity of the
particles of
bodies.

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B O O K II.

PARTICULAR CHEMISTRY.

SECTION I.

OF THE GENERAL PRINCIPLES OF BODIES.

C H A P. I.

CONCERNING THE GENERAL DIVISION OF CHEMICAL PRINCIPLES.

AMONG the various divisions or arrangements of chemical principles, that which follows their respective degrees of simplicity must undoubtedly prove the most useful, because the more compounded bodies will easily assume a regular order when their respective principles are known and properly classed. There is however a limit in the advantages that may be derived even from this method of division. The more we succeed in simplifying the principles of bodies, the more difficult it is to determine truly what passes in

PRINCIPLES
OF BODIES.
Arrangement.

G 2 chemical

**PRINCIPLES
OF BODIES.**

Arrangement.

chemical operations ; because these principles, when in their most distinct state, have the aerial form, and cannot therefore be managed or weighed without considerable difficulty. From this cause it is that, while we have no disputes concerning the changes of combination in grosser and less simple substances, the most eminent chemists often differ in their opinions concerning the transitions of first principles from one combination to another ; and are not agreed concerning the existence of some of them. The peculiar properties of bodies may be changed, either by the addition or subtraction of some of their component parts ; and it is easy to form a notion that such a change may also happen by a mere alteration in the disposition or relative arrangements of their parts, without any change in their quantities. To determine which of these events takes place, when we behold only the consequent change, is sometimes impracticable, for want of a sufficient number of facts ; and in most cases the complete investigation requires the unprejudiced and patient exertion of all the powers of the mind. It will be proper therefore, in an elementary arrangement, to fix our attention chiefly on the most palpable component parts of bodies, which are sufficiently simple ; and where they are not the simplest, to speak of their principles in the analytical method.

Enumeration.

The component parts of bodies are either,

1. Principles whose existence is doubtful : these are heat, light, and phlogiston.
2. Principles which have not been exhibited in a solid or fluid state, or dissolved in water, in any notable proportion :

proportion: these are vital air, phlogisticated air, and inflammable air. PRINCIPLES
OF BODIES.

Enumeration.

3. Water.

4. Earths.

5. Alkalis.

6. Acids.

7. Metals.

8. Mineral combustibles.

9. Parts of organized substances, whether obtained by mechanical pressure, by simple solution in water or ardent spirit, by a gentle or a strong heat, by the action of solvents, or by spontaneous decomposition.

The only general division of bodies at present referred to in the writings of modern chemists, is that by which they are classed into three kingdoms, called the animal, vegetable, and mineral kingdoms. The kind of bodies arranged in the two first kingdoms is obvious from the terms; and all other bodies are considered as belonging to the mineral kingdom. Animal, vegetable, and mineral kingdoms.

Alkalis, acids, and such compounds as they enter salt into, are distinguished generally by the name of salts. The leading character of salts is a strong tendency to combination, there being no bodies in nature which are not acted upon by some saline substance. This tendency appears in their eminent degree of solubility in water. All bodies known only by the name of salts are soluble in less than two hundred times their weight of boiling water. The same cause produces their sapidity, or taste, which was regarded by the earlier chemists as a distinctive character of salts.

Metals are sometimes classed with combustible bodies; and, strictly speaking, they are combustible. But

PRINCIPLES OF BODIES. as none of them possess this property in such a degree
as to burn away in the common air, without the co-
operation of other inflammable bodies, which are ne-
cessary to maintain their high temperature; and as
they possess other remarkable properties peculiar to
themselves—they require to be placed in a separate
class.

Metals.

C H A P. II.

CONCERNING HEAT, LIGHT, AND PHLOGISTON, CON-
SIDERED AS COMPONENT PARTS OF BODIES.

IT has already been stated, that the existence of heat, DOUBTFUL PRINCIPLES.
 as a peculiar substance, is not proved; and, among Heat.
 philosophers of the first eminence, there are several who Page 6. 21.
 think the opinion that it is a mere modification, is the
 most probable. With regard to light, the opinions of
 the world are less divided. It is generally taken for Light.
 granted that light is a substance, or an emanation of
 particles of prodigious minuteness, which are projected
 in right lines, with extreme velocity, from luminous
 bodies; and that they are repelled from all bodies at
 certain distances, and at less distances attracted, so as
 to produce all the effects of reflection, refraction, and
 inflection, in the rays they compose. These particles Newton's Op-
tics, sub fine.
 are supposed to be either of various magnitudes, or
 differently acted on by other bodies, and from that
 cause to be separable from each other; in which sepa-
 rate state they affect the organ of sight with the sen-
 sation of various colours.

Many philosophical writers have considered it as an Subtle Said.
 axiom, that a body cannot act where it is not*; and
 have

* It may be observed that this position is very doubtful. All our
 knowledge is derived from an observation of the actions which take
 place between bodies. Now we never see bodies act where they

DOUBTFUL
PRINCIPLES.

Light.

have thence inferred, that the universe is occupied by a subtle fluid, whose action causes bodies to approach and recede from each other in the phenomena of attraction and repulsion. Light is considered by some authors * as a modification of this fluid, in the same manner as sound is admitted to consist in an undulatory motion of the air, communicated from sonorous bodies. We shall not here examine the merits of this question, but shall only observe, that no decisive experiments have yet been offered in support of either opinion.

Burning lens,
or mirror.

When a great number of rays of light are made, either by a burning glass or concave speculum, to pass through a small space, they excite a most powerful heat in bodies placed in the focus. The strongest heat yet known is of this kind. The heat produced in bodies by the action of light, is in general greater, the more light is caused to disappear. Bodies which either transmit or reflect the light in large quantities, are very little heated by the focus of a burning apparatus. Similar coatings of black paint, the one upon a plate of iron, and the other upon a plate of pasteboard, being exposed in circumstances perfectly similar to the sun's rays, the heat produced was greater in the iron, though the mass

are, but always where they are not. In attraction and repulsion this is evident; and in impulse, there are the best reasons to conclude that the impelling body approaches within a certain distance of the impelled body, and then acts by its repulsive force without contact. Even the particles of bodies do not touch; for, if they did, how could a diminution of temperature bring them nearer together? Of the penetrability of matter we need not speak in this place.

* Of these the great Euler stands first. See his Letters to a German Princess.

of this last was near ten times that of the pasteboard *. **DOUBTFUL PRINCIPLES.**
 It has been often asserted, that heat and light are the same thing. But the light of a fire will pass through a pane of glass, and the heat will remain behind, as is most evidently shewn by interposing the glass between the fire and a concave metallic mirror†. The focus of the mirror, though as luminous as before, will produce no heat. A bright table-spoon may be used where a mirror is not at hand. The presence of light has a considerable effect upon the process of crystallization; and in many instances it produces a change in bodies of an opposite nature to that which they suffer from combustion. Light and heat differ.

During the combustion of inflammable bodies, we Phlogiston. perceive a continual escape of volatile matter; and as the fixed residue is usually found to be much less than the original weight of the body which has been burned, it was natural for the earlier chemists, who were unacquainted with the nature and quantity of the volatile products, to infer that combustion consisted in the escape of some principle which inflammable bodies possessed, but which was wanting in such as could not be burned. This doctrine has been occasionally modified till our time; and the experiments made by exposing to heat a metal that had been burned, together with another more inflammable body, in a closed vessel, in which the latter was consumed, while the former recovered its inflammability, were, till lately, received as undoubted proofs that the principle of inflammability or phlogiston

* Dr. George Fordyce, in Phil. Transf. Vol. lxxvii. p. 313.

† Scheele on Air and Fire, p. 70. English translation.—Mariotte in Mem. Acad. Par. 1682.

DOUBTFUL
PRINCIPLES.

Phlogiston.

Page 33.

had passed from the one body to the other. It was indeed urged as an objection, that metallic bodies, so far from losing weight by calcination, do really become heavier: and later experiments shewed that this increase of weight was gained from the air; the absolute necessity of whose presence in combustion had been formerly either overlooked, or slightly regarded. But this was explained from the doctrine of affinity, by the supposition that the pure air of the atmosphere, combining with the base of the combustible body, set its phlogiston, or fire, at liberty. The modern doctrine of heat however appears to shew, that the increase of temperature arises from the air, and not from the combustible body; and this consideration has led several eminent French chemists to reject phlogiston altogether*, and to consider the process of combustion as nothing else but the act of combination of vital air with the combustible body; the matter of heat, which according to them is combined with the air, being set at liberty.

Among the chemists who maintained the old opinion it became therefore an object of enquiry, whether the air absorbed in combustion really either expels, or combines with, any principle common to all inflammable bodies. For if this should be resolved in the affirmative, the substance found would be the

* This doctrine may be seen displayed at length in the notes annexed to Kirwan's Essay on Phlogiston, second edition. M. Lavoisier is the first of the chemists who explained and illustrated the new doctrine by a set of accurate experiments, and a judicious arrangement of the known facts; but M. Bayen may be considered as the first modern who, upon rational grounds, rejected the phlogiston. The excellent John Mayow is the father of this doctrine.

prin-

principle of inflammability or phlogiston. The evident way to determine this must be, to heat combustible bodies in closed vessels. The most predominant volatile product is, in these cases, found to be a very light, aerial matter, which is very inflammable when common air is present; and is known by the name of inflammable air. Mr. Kirwan first announced this as the phlogiston.

DOUBTFUL
PRINCIPLES,
Phlogiston.

The great question now is, whether inflammable air be contained in all combustible bodies, since they do not all emit it by mere heat; and it is evident that, if combustion can be effected without it in any one instance, it cannot be the indispensable and universal principle of inflammability. Its existence is denied in sulphur, phosphorus, charcoal, metals, and some other substances. It may however be obtained by heating these, if water be present: whether it is afforded by the substance under examination, or by the water, is therefore the subject of controversy.

We may resume this subject as we advance; but enough has been said in this chapter to shew the learner that the existence of heat, light, and phlogiston, as chemical principles of bodies, is not yet incontrovertibly established.

C H A P. III.

OF PHLOGISTICATED, DEPHLOGISTICATED OR VITAL,
AND INFLAMMABLE AIR, AND OF THE
COMPOSITION AND GENERAL PRO-
PERTIES OF WATER.

COMBUS-
TION.

Page 50.

Effects of com-
bustion on
common air.

Observations.

WHENEVER combustion, or an equivalent process, is carried on in a vessel containing atmospherical air, which is inclosed either by inverting the vessel over mercury, or by stopping its aperture in a proper manner, it is found that the process ceases after a certain time; and that the remaining air, which is about three-fourths of the whole bulk, is of such a nature, as to be incapable of maintaining combustion, or supporting the life of animals.

From this experiment it is clear that one of the following deductions must be true: 1. The combustible body has emitted some principle which, by combining with the air, has rendered it unfit for the purpose of combustion: Or, 2. It has absorbed part of the air, which was fit for that purpose, and has left a residue which is of a different nature: Or, 3. Both events have happened; namely, that the pure part of the air has been absorbed, and a principle has been emitted which has changed the original properties of the remainder.

The facts must clear up these theories. The first cannot be altogether true, because the residual air is not only of less bulk, but of less specific gravity, and the burned body is heavier than before. The air cannot

cannot therefore have received so much as it has lost. COMBUSTION.
 The second is the doctrine of the philosophers who Opinions.
 deny the existence of phlogiston, or a principle of inflammability. And the third must be adopted by those who maintain that such a principle escapes from bodies during combustion. This residue was called phlogisticated air, in consequence of such an opinion.

In the opinion that inflammable air is the phlogiston, Phlogiston.
 it is not necessary to reject the second deduction. For the pure or vital part of the air may unite with inflammable air, supposed to be in a fixed state in the combustible body; and if the product of this union remain fixed, it is plain that the residue of the air after combustion will be the same as it would have been if the vital part had been absorbed by any other fixed body. Or if the vital air be absorbed while the inflammable air is disengaged, and unites with the aerial residue, this residue will not be heavier than before, unless the inflammable air it has gained exceeds in weight the vital air it has lost.

It is rendered more probable that the air of the atmosphere consists of a mixture of a vital and a noxious part, by the fact, that, when fixed bodies have been burned or calcined (for example, mercury converted into precipitate per se), the vital air may be again extricated from some of them. This is found to maintain combustion in the most effectual manner, and is almost totally absorbed in that process, instead of leaving a residue supposed to be changed by phlogistication. And, on the other hand, there is no unequivocal proof that vital air can be obtained from the phlogisticated part by any operation whatever. Composition of the atmosphere.

Vital

VITAL AIR.
 Substances
 which afford
 vital air.

Vital air may be obtained by heat from nitre, from alum, from mercury calcined without addition, and usually called precipitate per se; from red precipitate, from minium, from manganese, and from lapis calaminaris. Most nitrous and vitriolic salts afford it by heat. It is contained in the bladders of sea-weed, and in waters. The green vegetable matter formed in water emits it when exposed to the sun's light; and it is found in general that the leaves of plants, in like circumstances, emit vital air. Whence it appears that there are abundant provisions for restoring the purity of the air, which is continually injured by combustion, respiration, fermentation, and other processes.

Respiration is
 a process of
 the same kind
 as combustion.

The respiration of animals produces the same effect on air as combustion does; and their constant heat appears to be an effect of the same nature. When an animal is included in a limited quantity of atmospheric air, it dies as soon as the air is vitiated. Vital air, in like circumstances, maintains the life of animals much longer than common air.

Vegetables af-
 fect the air.

Vegetables do not thrive in vital air. These appear to render common air purer, by absorbing its phlogisticated or noxious part. They emit vital air when the sun shines on them. This is supposed to arise from the decomposition of water.

Nitrous air
 used as a test.

Several of the metals, and other combustible substances, when dissolved in spirit of nitre, afford or extricate, by an effervescence, a kind of air called nitrous air, of which we shall more particularly speak in its place. Mercury is one of these metals. If this air be mixed with any other air in which vital air is contained, it unites with this last, and forms red fumes,

which

which fall down, and are found to consist of nitrous acid. The air itself is diminished in bulk by the loss; and hence the nitrous air becomes a test of the goodness of respirable air. For the diminution is greater the greater the quantity of vital air.

INFLAM-
MABLE AIR.

All animal or vegetable substances which can be burned in the open air, charcoal excepted, will afford inflammable air, if heated in closed vessels. This is usually mixed with air of other kinds, and with oleaginous matter. Charcoal and several metals afford inflammable air by heat, if water be present. Some metallic substances, during their solution in acids, afford or extricate inflammable air, which is of the purest kind. This fluid is very light, according to its purity. It is usually about ten times as light as an equal bulk of common air; but it is said to have been obtained seventeen times lighter*. The common process for obtaining it is, to dissolve iron filings or shavings in diluted vitriolic acid.

Substances
which afford
inflammable
air.

If a mixture of about two parts, by measure, of inflammable air, with one of vital air, be set on fire, in a strong closed vessel, which may be done by the electric spark, the airs, if pure, will almost totally disappear, and the product will be water and an acid. Till lately, the produce was thought to be mere water; and several eminent chemists at Paris have strongly insisted that it was equal in weight to the two airs made use of. This agreement however has never been proved†; and, as every kind of air usually

Water produced by combustion of vital and inflammable air.

* By Morveau. See the *Aérostat de Dijon*.

† When we consider the great bulk and small weight of air, the magnitude of the apparatus, and the imperfection of the best balances,

WATER.
 Whether wa-
 ter be a com-
 pound.

usually holds a large proportion of water in solution, from which the aqueous product might be derived, it still remains a problem to be decided, whether water, with respect to the present state of our knowledge, be a simple or a compound substance. For the water may either be formed by the union of the two airs, or the real airs may be totally employed in forming the acid, while the water is simply condensed upon their losing the aerial form.

The extensive
 utility of wa-
 ter:

Water is a substance which enters into so many operations of nature and art, that a full description of its properties would include most of the properties of other bodies. Its weight is used as the measure of specific gravity; its capacity for heat is assumed as the standard of comparison for other bodies; its temperature at the changes from solidity to fluidity and to the elastic state, is taken as the fixed points for thermometers; and, in a word, the solubility of bodies denotes, in general, the action which this substance exerts upon them.

—its general
 properties.

Water being usually met with in these climates in the fluid state, its properties are in most cases treated of under that form. If it be heated it gradually expands, and is converted into vapour at 212° of Fahrenheit, with such rapidity as to counteract the effect of heat in raising its temperature. In a strong closed metallic vessel it may be heated nearly red hot, and in

Page 18.

balances, none of which in practice weigh beyond five places of figures (p. 67—69), we shall find sufficient reasons to question the accuracy of conclusions, which suppose the quantities of air and water to be rigorously ascertained. These reasons are still more enforced by the consideration, that the experiments of Dr. Priestley and M. Lavoisier do not agree.

this

this state its solvent powers are greatly increased. If the vessel be opened, steam suddenly rushes out, and the temperature of the fluid falls instantly to 212° . When water is cooled, it gradually contracts till within 8°

WATER.
General properties of water.

of freezing, and then expands till it freezes. The parts of the water which first become solid by freezing, have the form of sword-blades, crossing each other at angles of 60 degrees. It will shoot out into this form in the open air, as may be seen in snow or hoar frost upon trees. Ice is considerably lighter than water, and therefore floats upon it. The expansion of ice at the time of its formation is made with such force as to burst the strongest metallic vessels: and the expansion of steam is prodigiously great. This last power, being very manageable, by transferring greater or less quantities of steam into the vessels of apparatus, or by condensing it, has been applied to the most important mechanical uses in the steam engine, and will doubtless be applied to many more.

Ice.

When water is included in a metallic globe or vessel, called the eolipile, which has only a very small aperture, and it is then made to boil, the steam issues out very violently, and will strongly urge a fire in the same manner as bellows. This has been thought to prove a decomposition of the water. But it is not the steam which excites the fire, but the air it drives before it. For an eolipile will not produce this, but the contrary effect, unless a body of air be interposed between its aperture and the fire*.

Effects of the eolipile.

The density of water† is such that a cubic foot

Density of water

* Lewis's Philosophical Commerce of Arts, p. 21.

† This was found by Cotes, who says it is very nearly so. See his Hydrostatical Lectures, p. 76, second edition.

WATER.

Specific gravity
of water.

What waters
are purest.

weighs 1000 ounces avoirdupois weight. This fortunate concurrence of unity of measure with a round number in the weight, renders the common tables of specific gravities very useful in computations. For the numbers will denote the avoirdupois ounces in a cubic foot of each substance, provided the specific gravity of water be taken to be 1000.

The purest common waters are the lightest, and lather well with soap. For chemical purposes, water should be boiled on a common fire for a short time, to dissipate any volatile animal or vegetable impregnation it may possess, and afterwards distilled to about one half. The water which comes over is very pure, and the accurate chemist should use no other. On account of the extensive use and importance of distilled water, it is advisable not to perform this operation but with vessels kept for that and no other purpose.

CHAP. IV.

OF THE SIMPLE OR PRIMITIVE EARTHS.

CHEMISTS distinguish such substances by the name of pure earth, as are brittle, incombustible, infusible by the heat of furnaces, not soluble in several hundred times their weight of water, and destitute of metallic splendour. There are few earthy substances which may not be reduced by analysis to one of the five following primitive earths:—the siliceous, argillaceous, calcareous, ponderous, and magnesian earths; or otherwise, taken substantively, they are called silex, clay, lime, barytes, and magnesia.

EARTHS.

Five primitive earths.

The adamantine spar, the jargon of Ceylon, and a New earths, mineral substance from New South Wales, have afforded earthy substances which, as far as experiments have yet determined, are different from any of these five. But they will not materially affect the general arrangement of chemistry, until future researches shall have proved that they are more abundantly found than at present we have reason to suspect.

In some systems a distinction is made between earths and stones; but this is of no utility in the enquiry respecting their component parts and properties. A stone is nothing more than a hard earthy mass, and an earth in powder is an aggregate of very minute stones.

Siliceous earth abounds in all natural bodies which are hard enough to strike fire with steel. Of these

EARTHS.

rock crystal, quartz, flint, gritstone, jasper, and most of the precious stones or gems, are the chief specimens. Like all other simple substances, it is never found pure in nature. The leading or principal character of this earth is, that it is not perceptibly acted upon by any acid but that of fluor spar. Alkalis dissolve it in the moist as well as in the dry way, but most efficaciously and in all proportions in the latter. Hence the method of obtaining siliceous earth in a state of purity consists in dissolving crystal or quartz in a large proportion of fixed alkali in strong fusion: for example, four parts by weight of the salt to one of the earth. This combination will unite with water, in which it must be dissolved. The solution is usually called liquor of flints. An excess of acid being added, will combine with the alkali, and such other earths as may have existed in the natural specimen; and the pure siliceous earth, being insoluble in water, will fall to the bottom. Repeated washing in distilled water will separate all the extraneous matter from these particles, which, when dried, consist of siliceous earth uncombined with any other substance.

Pure siliceous earth.

The particles of siliceous earth, thus obtained, are in a state of such minute division, that they will remain suspended for a considerable time in water; and this fluid, violently heated in a strong closed vessel, will dissolve a portion of it. Siliceous earth is unalterable in the most violent heats chemistry can produce in a furnace. Rock crystal, which is the purest specimen of this earth, of which it contains ninety three parts in the hundred, has been fused by flame urged upon it by a stream of dephlogisticated air from a blow-pipe. With
fixed

fixed alkalis, in the proportion of about double its own weight, it forms glass. Calcined metals, especially lead, also dissolve it, and form glass by fusion. The combination of this earth with fluor acid is very sparingly soluble in water. EARTHS.

The principal natural specimens of argillaceous earth are, clays, properly so called, marles, boles, slates or schistus, and mica. In none of these, except the flagstone, does the argillaceous earth amount to so much as half their weight, though their predominating qualities appear to depend upon it. The most obvious characters of this earth are, an adhesion to the tongue, or any wet and soft body, in the more solid specimens; and a remarkable tenacity, ductility, or kneadability serve to distinguish moistened clays in a most eminent degree. It is soluble in acids, but alkalis act much less upon it, either in the dry or moist way, than they do on siliceous earth. Alum is a combination of argillaceous earth with vitriolic acid. If the concrete volatile alkali be added to a solution of pure alum, the alkali and acid unite, while the clay falls to the bottom, united only with a small quantity of fixed air. The fluid must be abstracted by decantation, and the precipitate washed with distilled water, and dried. Argillaceous earth.

Clays may be easily diffused and suspended in water, but are not soluble in any sensible degree. The sudden application of strong heat hardens their external parts, which afterwards burst by the explosion of the moisture within. By a more gradual heat, pure clay contracts very much, becomes hard and full of cracks or fissures: The presence of siliceous earth in common

EARTHS.

Pottery.

Thermometer
for strong heat.

clays, where it usually constitutes above half the weight, renders the contraction more uniform throughout, and prevents the cracks, probably in no other way than by rendering them more numerous, and too small to be perceived. When thus baked, it constitutes all the varieties of bricks, pottery, and porcelain. These, if baked in a strong heat, give fire with steel; a property that may be attributed to the siliceous earth they contain, which cannot act on the steel unless firmly set in the hardened clay. The dimensions of pottery are less, the greater the heat to which the article has been subjected. On this property is constructed a thermometer for measuring the heat of furnaces, by igniting a small brick of known dimensions therein, and afterwards measuring its contraction *. Baked clay is no longer kneadable with water, though as finely pulverized as mechanical means can go. Hence it has been inferred that clays owe their ductility to a kind of gluten which is supposed to be dissipated by heat. They recover that property however by solution in an acid and precipitation; whence it should seem to depend either on a minute portion of acid contained in clays, or the smallness of the particles when precipitated.

Calcareous
earth:

Calcareous earth, or lime, predominates in most stones which are soft enough to be scratched with a knife. These are chalk, limestone, marble, spars, gypsum, or plaster stone, and various others. As the lime is most frequently combined with fixed air, it is usual for mineralists to drop a small quantity of nitrous acid

* See Wedgwood in Phil. Transf. vol. lxxii. and lxxiv.

upon

upon the stones they are desirous of classing; and if it froths by the escape of the fixed air, they conclude that lime enters into the composition. To obtain pure calcareous earth, powdered chalk must be repeatedly boiled in water, which will deprive it of the saline impurities it frequently contains. It must then be dissolved in distilled vinegar, and precipitated by the addition of concrete volatile alkali. The precipitate, when well washed and dried, will consist of lime united to fixed air; the latter of which may be driven off by heat, if necessary.

EARTHS.

Method of obtaining it pure.

If chalk, marble, limestone, spar, or any other specimens of this earth, containing fixed air, be exposed to continued ignition, they give out fixed air and water, to the amount of near half their weight. The remainder, consisting chiefly of lime, has a strong tendency to combination, and attracts water very powerfully. The addition of water to lime produces a very considerable heat, attended with noise, and agitation of the parts, which break asunder; and a phosphoric light is seen if the experiment be made in the dark. Lime thus saturated with water is said to be slaked. Water dissolves about one seven hundredth part of its weight of lime, and is then called lime-water. This solution has an acrid taste, and turns syrup of violets to a green colour. If lime-water be exposed to the open air, the lime attracts fixed air, and is by that means converted into chalk; which, not being soluble in water, forms a crust on the surface, formerly called cream of lime, that, when of a certain thickness, breaks and falls to the bottom: and in this way the whole of the lime will in time be separated.

Lime, or quicklime.

Slaked lime.

EARTHS.

Mortar.

The paste of lime and water, called mortar, has a degree of adhesion and ductility, though much less than clay. When dry, it is friable like chalk. A mixture of sand, or broken earthen vessels, greatly increases its firmness, which it seems to effect by rendering it more difficult for the parts to be removed with respect to each other. When mortar is left to dry by the gradual evaporation of its superfluous water, it is very long before it obtains its utmost degree of firmness. But if dry quick-lime be mixed with mortar, it gradually absorbs the superfluous water, and the mass becomes solid in a very short time.

Gypsum, or
plaster of Paris.

Gypsum, or plaster of Paris, consists of lime united to the vitriolic acid, together with water. If this substance be exposed to a moderate heat, part of the water is driven off. The dry powder which remains may be mixed with water to the consistence of thin paste, and poured into a mould; and soon afterwards it suddenly becomes solid, at the same time that it is a little heated, and its bulk somewhat increased. This effect may be explained by observing that the particles of the gypsum are at first simply wetted by the water, in the same manner as happens with clay; and for that reason no other effect takes place, than the production of an imperfect degree of fluidity, from the motion of the parts among each other being facilitated: but when the water, by the gradual progress of the action between it and the dried gypsum, becomes combined in the same manner as before the calcination, it is absorbed, and enters into the composition of a solid body; the imperfect fluidity, arising from the presence of uncombined water, disappears, heat is developed, and the

whole mass takes the solid form. The use of this material for casting small statues, medallions, and other ornaments, is well known.

EARTHS.

The earth which enters into the composition of the bones of animals and shells of fish is calcareous. In the former it is united with the phosphoric acid, and in the latter with fixed air.

Animal earth.

Ponderous earth, or barytes, is not found very abundantly, or in large continued masses, but chiefly in the vicinity of mines, or veins of metal. Its specimens are either aerated ponderous spar, which has been found at Alston Moor, in Cumberland *, and considerably resembles alum, but is of a striated texture: or vitrified ponderous earth, either in the form of a transparent spar or an opaque earth; of a white, grey, or fawn colour; frequently of no regular figure, but often in the peculiar figure of a number of small convex lenses set edgewise in a ground. The opaque specimens have been called marmor metallicum, on account of their great weight; but the English miners call it cawk. Most specimens of this earth are above four times the weight of an equal bulk of water, which constitutes an obvious difference between this and calcareous earth, which is little more than twice that weight: they are

Ponderous earth.

Ponderous spar, or marmor metallicum.

* Analyzed by Dr. Withering. See Phil. Transf. vol. lxxiv. Mr. Watt, jun. in the third volume of the Manchester Memoirs, gives reasons for concluding that this specimen came from the lead mine of Anglezark, near Chorley, in Lancashire, where it is plentifully found. He observes that this is the only mine in England which is known to afford it. It has also been found in the mines of Strontion and Dungleass, near Dumbarton, in Scotland.

scarcely,

EARTHS. scarcely, if at all, soluble in water. The liver stone, or lapis hepaticus, contains about one third part of this earth. If ponderous spar be fused with about twice its weight of fixed alkali, its acid will unite with this last, and form a salt, which may be washed off by water, the ponderous earth remaining behind in combination with fixed air. This may be deprived of its fixed air by a strong heat, which converts it into a state perfectly resembling quick-lime in taste, and exhibiting similar phenomena with water.

To obtain pure ponderous earth.

The natural aerated ponderous earth differs from that produced by art, in the circumstance that it contains no water; and to this it seems to be owing that it does not lose its fixed air by mere heat.

Native aerated ponderous earth.

Though this earth resembles lime in several respects, yet its combinations differ from those of the latter, both in weight, and so many other respects, as evidently shew that there is no reason to consider them as one and the same substance. It is combinable with acids.

This earth differs from lime.

From several properties in which ponderous earth has been observed to resemble metallic substances, it has been suspected to be of that class: but this suspicion has not yet been verified by experiment.

Ponderous earth supposed to be metallic

Magnesia. Most of the native specimens of magnesian earth are remarkable for a certain soapy or greasy feel. Of these the most common are, steatites, of a greenish colour, and soft enough to be scraped with the nail; soap rock; lapis ollaris, or Spanish chalk, of a yellow or whitish colour, but rarely black, rather harder than steatites, and so easily wrought and turned, that pots

are

are made of it. Asbestos, amianthus, and the Venetian and Muscovy talc, are included in this genus.

EARTHS.

The combination of vitriolic acid and magnesia is Epſom ſalt. very ſoluble in water, in which it remarkably differs from the combinations of the ſame acid with the calcareous or ponderous earths. This compound is known by the name of Epſom ſalt, and is found in ſome waters; but is moſt frequently obtained, for commercial purpoſes, from ſea water, after the common ſalt has been extracted by evaporation. If mild volatile alkali be added to a ſolution of Epſom ſalt, the alkali unites with the acid, and part of the earth falls to the bottom, combined with fixed air, which, when well waſhed, is mild magnesia. Mild magnesia.

Mild magnesia is a light impalpable powder, of a Pure magnesia. white colour; and forms a paſte with water, which has not much coheſion. Heat drives off its fixed air, and renders it ſomewhat harſher to the feel; but not cauſtic, nor ſoluble in water, like lime. Its taſte is very flight in either ſtate. The ſtrongest heat does not affect it, if pure. Acids diſſolve it, but alkalis ſcarcely affect it in the dry way.

As the various compounds of bodies uſually poſſeſs Union of earths by fuſion. properties very different from thoſe of their principles, it is accordingly found that the earths, though infuſible alone, are not ſo when mixed together. The calcareous earth is found to be the ſolvent of other earths, for they are all rendered fuſible by a proper proportion of it. And theſe compounds of two earths will diſſolve ſtill more. So that though one hundred parts of lime will diſſolve very little filiceous earth; yet a compoſition of one hundred of lime with fifty of magnesia,

EARTHS.

magnesia, will dissolve one hundred of siliceous earth; and this last compound will take up more magnesia than the mere calcareous earth could have done. Any three of the earths, in equal parts, will vitrify into a perfect glass, provided calcareous earth be one among them.

Supposed reduction of the earths.

It has lately been asserted, upon good authority, that the argillaceous, calcareous, ponderous, and magnesian earths were reduced to the metallic state by strongly heating them with charcoal*. But however it may be probable from analogy that such reductions may be within the limits of possibility, it is at present generally understood that the metallic matter obtained in these experiments consisted of iron afforded by the crucibles made use of.

The new earths.

We shall frequently have occasion to treat of the five ancient earths, as their various combinations present themselves to our notice: but the three lately discovered earthy substances not having been subjected to experiments, except in the laboratories of the discoverers, will not again come under discussion in the present work. On this account therefore it will be proper to speak rather more fully respecting them than the preceding, and likewise to enter more minutely into the description of processes than we might otherwise do in this early part of our work.

Characters of adamantine spar:

A stone has been within a few years brought from the East, which has received the name of Adamantine Spar. Two varieties are known†. The first

* Journal de Phys. 1790.

† Extracts from the Memoir of M. Klaproth. Annales de Chimie, i. 183.

comes from China; it is crystallized in six-sided prisms, without pyramids, varying in their length from half an inch to one inch, and in breadth near one inch; its colour is grey, of different shades. Whole pieces are opaque, but thinner fragments are transparent: its texture is sparry, and it breaks with a polish. The sparry texture produces a slight striated appearance on its surface: its hardness is so great, that it not only cuts glass like a diamond, but it marks rock crystal, and other hard stones: its specific gravity is 3.710, and in some specimens as high as 4.180. Small grains of magnetic calx of iron are sometimes disseminated through this stone.

EARTHS.

—from China,

The second variety is whiter, more decidedly spathose in its texture, and the grains of calx of iron are smaller, and merely adhere to its surface. It is called corundum at Bombay*. At Madras it is known by the name of grinding spar.

—from Bombay.

M. Klaproth attempted the analysis of this stone by keeping it in fusion with fifteen times its weight of caustic mineral alkali in a silver crucible for five hours; then adding boiling water, filtering and saturating the alkali with an acid, which consequently threw down that portion of earth which had combined with the alkali. The undecomposed part was repeatedly digested with concentrated boiling acids. The stone was not completely decomposed till after twelve repetitions of this process; and it was found to consist of two parts clay, and one of an earth not soluble by fusion in alkalis, nor acted upon by acids. It differs

Analysis of
adamantine
spar.

Peculiar earth.

* Various specimens have been found in France. See De Morveau in the *Annales de Chimie*, i. 188.

there-

EARTHS.

Characters of
the jargon of
Ceylon.

therefore from siliceous earth, as well as from the four other soluble earths.

The same chemist examined the jargon of Ceylon by processes nearly similar*. The colour of this stone is pale, of a yellowish green, inclining to red; forming upon the whole a kind of smoky grey tinge. Its regular figure is that of a four-sided prism, terminated by two obtuse pyramids, composed each of four isosceles triangles. Its specific gravity exceeds that of any other stone, being 4.615.

Pieces of this stone being ignited, thrown into water to render it less coherent, and then levigated upon porphyry, were fused in the silver crucible, with a large proportion of caustic fixed alkali. The solution was treated with water and with marine acid, which took up a small part, and left a residue, which was again fused with alkali, and treated as before. After several repetitions of this process, the whole was dissolved. By saturating the acid with mild vegetable alkali, the earthy matter was thrown down. Digestion of part of this precipitate with marine, and part with vitriolic acids, indicated, after a due application of chemical methods, a considerable portion of siliceous earth, with a minute quantity of iron and nickel, and a much larger proportion of an earth which remained suspended on account of its solubility in acids. This

Peculiar earth. earth was found to differ in its properties from every other yet known: its solubility sufficiently distinguishes it from flint. When precipitated by mild alkali, it did not become effervescent, like lime or magnesia;

* See the Memoir at length in the Journal de Physique for March 1790.

neither

neither did it, like them, form selenite or Epsom salt with vitriolic acid. It did not form alum with the vitriolic acid, as clay does. It differed essentially from ponderous earth, in its not being precipitable by the Prussian alkali; and in forming a salt with vitriolic acid, which was exceedingly different from ponderous spar. This earth was not soluble either in microcosmic salt, or in mineral alkali, when treated by the blow-pipe; but borax dissolved it. The jargon was found to contain in the hundred parts $31\frac{1}{2}$ silica, $\frac{1}{2}$ calx of iron containing nickel, and 68 of this peculiar earth.

EARTHS.

A mineral from New South Wales was put into the hands of Mr. Wedgwood by Sir J. Banks*. It consisted of a mixture of fine white sand, a soft white earth, some colourless micaceous particles, and a few black ones, resembling black mica or black lead. Mr. Wedgwood made some experiments upon it, but does not appear to have completely analysed the mass, most probably on account of its small quantity.

Mineral from
New South
Wales :

Neither the nitrous nor vitriolic acids, concentrated or diluted, hot or cold, were found to take up any thing from this mineral which could be precipitated by alkalis; excepting that the strong vitriolic acid, by due management, indicated a minute portion of clay. But the marine acid, by digestion near its boiling heat, acted on it with frequent explosive bursts, and took up about one fifth of the whole. The crude mineral, pulverised and calcined, lost its blackness, and one fourth of its weight, but was found to be as difficult of solution as before. Water added to the marine

—subjected to
experiments.

* Wedgwood in the *Philos. Transf.* for 1790, page 306.

solution,

EARTHS.
 {
 White earthy
 matter.

solution, threw down a white precipitate; and the separation was so complete, that, after an addition of eight or nine times the whole bulk of water, there remained nothing in solution that alkali could precipitate. This white matter was insoluble in water, and also in the nitrous or vitriolic acids, and in alkaline solutions. Strong marine acid took it up as before, by the assistance of the same degree of heat. A certain precise quantity of nitrous acid added to the marine solution, kept the white matter suspended, even when diluted with water. Strong vitriolic acid did not throw down the white matter from the marine solution; but when the quantity added was nearly equal to that of the solution, part of the marine acid was extricated in white fumes, with effervescence. The mixture, heated nearly to boiling, becomes transparent, and continues so in the cold. This solution is also precipitable by water, and the precipitate is soluble in marine acid.

Marine solution of the
 white matter:

The saturated marine solution does not crystallize by evaporation, but affords a deliquescent mass, which is not corrosive, and parts with its acid in an heat near ignition. Prussian alkali does not precipitate the marine solution; but all the alkalis, whether mild or caustic, occasioned copious precipitations, which were soluble in marine acid, and thence precipitable by water in the original state.

—fusibility.

This white precipitate is much more fusible than any of the other simple earths. In a heat between 142 and 156 degrees of Wedgwood's thermometer, which is nearly as high as is produced in a small air furnace, it melted in contact with clay, with flint, with chalk, with lime, with magnesia, with pure ponderous earth, and

and with ponderous spar, in several different experiments. In a hole scooped in chalk it ran into a smooth whitish opake bead, not at all adherent to the chalk itself; and in a cavity in charcoal it likewise fused, but did not seem to undergo any revivification. Part of this was soluble in boiling marine acid, and precipitable by water, as at first; but an accident prevented the determination whether the whole was soluble.

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It appears proper therefore to consider the white matter as a new earth; directly soluble in no menstruum but marine acid, or perhaps its compounds; not crystallizable in this combination; precipitable by water, and not by the Prussian alkali; parting with its acid in a heat below ignition; and fusible in a degree of heat not very much exceeding that required to melt cast iron. Peculiar earth.

The black substance which seems to have composed about one-fifth part of the crude mineral, was found to resemble plumbago in its leading properties, but its residue did not appear to be iron. The remaining three-fifths of the mineral which resisted the humid attacks in Mr. Wedgwood's experiments, was probably flex; but he does not speak of any direct examination of its properties by fusion with alkalis, the sparry acid, or otherwise. Other parts of the mineral.

In the second part of the Philosophical Transactions for 1794, there is an account of a mineral substance called strontionite, from the place Strontion in Scotland, where it is found in granite rocks, accompanied by galena and witherite, by which last name I suppose New mineral from Strontion.

I

Mr.

EARTHS.

External characters of strontionite.

Mr. Schmeisser, the author of the analysis, means the native aërated ponderous earth.

In all the specimens this author had seen he could not discover any regular crystallized figure. The specimen which he submitted to experiment was in solid masses, apparently composed of long fibres, closely adhering together, and disposed in radiations; its colour was an asparagus green, deeper towards the center of the mass. When broken, the surface was a little shining in certain directions; the fragments rather bar-like, and somewhat brittle.

Some specimens exhibit only light shades of this colour, and appear to be composed of long thin bars, which are often separated from each other towards the extremity.

The specimen examined was semi-transparent; but the most of it rather inclining to opaque. A hard knife scratched it, but it could not be scraped. Its specific gravity was 3.586 at 60° degrees of temperature.

The first experiments, which pointed out a distinction between the basis of this stone and the ponderous earth of Scheele, were made, by Dr. Crawford's desire, by his assistant Mr. Cruikshank, and were afterwards repeated by himself. The account of these is inserted in the second volume of the Medical Communications, by reference to which Mr. Schmeisser very properly does justice to the original discoverers.

Analysis of strontionite by M. Schmeisser.

Mr. S. found, 1. That the powder of strontionite was not acted on by boiling water:—2. Nor by the vitriolic acid.—3. But the nitrous and marine acids severally

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Characters and
habitudes of
strontionite.

severally and entirely dissolved it, with strong effervescence: the elastic fluid which escaped was pure fixed air. 4. Diluted vitriolic acid, added to the diluted nitrous and marine solutions, threw down a white precipitate. 5. Before the blow-pipe, a piece of the strontionite did not crackle nor split asunder, nor did it melt, even when exposed to white heat; but

discovered a very bright phosphorescent light, became more brittle, lost its greenish cast, and then was partly soluble in water. A long continuance of the white heat deprived it of very little of its weight, and it still effervesced with acids. 6. With borax and with soda it melted with ebullition; but neither a blue nor a green colour was exhibited by fusion with the former. 7. Fluid volatile alkali did not extract any blue colour from the powdered substance, nor when added to the acid solutions. The solutions in the marine and nitrous acids were colourless. A piece of paper, dipped in the nitrous solution, burned with a red flame. 8. The Prussian alkali, added to a saturated solution, threw down a very slight quantity of blue precipitate. 9. Acid of sugar, added to the diluted solution, afforded a very slight precipitate. 10. The remaining liquid of the foregoing experiments was mixed with vitriolic acid until no more precipitate took place, after which the remaining filtered liquor afforded no earth when purified pot-ash was added to saturation. 11. The saturated nitrous solution afforded crystals by evaporation, which were permanent in the air, and exhibited triangular and sexangular plates. 12. The saturated marine solution exhibited on evaporation long six-sided prisms, which

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 Analysis of
 strontionite.

have the broad alternating with the narrow fides, and terminate in obtuse trihedral pyramids. This was observed by Dr. Crawford, who also found that the salt formed of the substance with acids dissolved in water produced five times more cold than the salt from the barytes in the same acid: that the salt formed by marine acid and this substance was much more soluble in warm water than in cold, whilst the muriat of barytes is nearly as soluble in cold as in warm water: that one ounce of distilled water dissolves three times as much of the muriat of strontionite as of the muriat of barytes, which makes a distinction between the basis of this substance and the barytes. 13. Nitrous acid added to the marine solution of strontionite occasioned a decomposition: 14. The earth was procured in a distinct state by solution in marine acid, precipitation by diluted vitriolic acid, subsequent drying and decomposition by means of heat with purified pot-ash, washing with water, and calcination. The quantity of fixed air contained in this earth was then proportionally ascertained by solution in acid. Mr. Schmeisser then found that a hundred grains of specific vitriolic acid, by which I suppose he means the particular acid he made use of, required 133 grains of the pure earth for saturation; but that 150 grains of pure ponderous earth were required for the same purpose: that 100 grains of nitrous acid required 94 grains of this earth, but 120 grains of the ponderous earth for its saturation; and that 100 grains of marine acid required 56 of this earth, but 96 of the ponderous.

Conclusions
 from the ana-
 lysis of stron-
 tionite.

Hence Mr. Schmeisser concludes, 1. That the native mineral contained no saline matter:—2. That it contained

contained fixed air:—and 3, an earth similar to the ponderous earth in its habitudes with the vitriolic acid. 4. No water of crystallization. 5. No cobalt nor copper. 6. A small portion of iron. 7. Some calcareous earth. 8. No argillaceous nor magnesian earth:—and 9. That the earthy basis is of a different nature from ponderous earth.

EARTHS.
Strontionite.

In order to ascertain the quantity or proportion of component parts of this substance, he dissolved 100 grains in acid, which yielded 30 grains of fixed air. Half a grain of calcareous earth was precipitated by acid of sugar, and the remaining solution yielded by decomposition 68 grains of the peculiar earth which may be called Strontion earth. The remaining weight may be accounted for from the substance which gives it the colour, which from comparative experiments Mr. Schmeisser supposes to be phosphorated iron and manganese.

The substance with which it was accompanied was crystallized in six-sided prisms, with pyramids, colourless, semi-transparent, rather opaque towards the basis, and less hard than the other substance. By analysis it was found to contain 70 grains of ponderous earth, 15 grains of fixed air, and 12 of calcareous earth.

C H A P. V.

OF THE SIMPLER SALTS; NAMELY, ALKALIS AND
ACIDS.

ALKALIS.

Characters.

THE alkalis are three in number; the vegetable, the mineral, and the volatile alkali. Of these the two former are distinguished by the general appellation of fixed alkalis. The general properties of fixed alkalis are—1. They change the blue syrup of violets to a green. 2. Their taste is peculiar, and disagreeably caustic, even when diluted with water. 3. They have a strong attraction for water, with which they unite in all proportions, and even attract it in sufficient quantities from the atmosphere to become fluid. 4. They combine with acids by a stronger affinity than is possessed by most other substances, at a moderate temperature. 5. Most inflammable substances are acted upon by them. 6. They melt in a moderate heat, and in a stronger heat they are volatilized. 7. In the dry way they dissolve earths, and the calces of metals.

Vegetable
fixed alkali.

The vegetable fixed alkali is found in some salts which may be said to be of the mineral kingdom; but it is obtained for all the purposes of trade and science from vegetable matters. Of this there are several kinds, which differ only in the respective quantities and nature of the impurities they contain. The cendres gravelées is a strong alkali, made by burning the husks of grapes and wine-lees. Pot-ash is procured from

from wood-ashes, and is very far from being pure. ALKALIS.
 Most vegetables afford this alkali by burning them, Methods of,
 and mixing their ashes with pure water; which, after procuring the
 decantation or filtering, may be evaporated, and will vegetable al-
 leave the salt behind. The purest is obtained by kali.
 wrapping tartar in wetted brown paper, and placing
 the parcels in beds or strata alternately with charcoal
 in a furnace. The whole is then to be set on fire,
 and the fire continued till the blackening smoke ceases
 to rise. If the heat be too intense, the alkali will
 melt, and mix with the impurities of the coal; but
 when the process is well conducted, the parcels may
 be taken out entire. By lixiviation or solution in pure
 water, with subsequent filtration, evaporation, drying,
 and calcining in a low heat, the alkali is obtained very
 white, and contains a considerable portion of fixed air.
 This might be driven off by heat; but it is not neces-
 sary to be done in that way, as it would be attended
 with some danger of the salt corroding the vessel, and
 becoming less pure. The vegetable alkali is known in
 the shops by the name of salt of tartar; but most
 chemists in London sell the impure alkali of pot-ash by
 this name.

It is not easy to purify the common vegetable alkali Purifying of al-
 as met with in trade, and it is seldom attempted. The kalis.
 chemist is not under any necessity to employ his time
 in procuring the alkalis absolutely disengaged from all
 other matter, as they will be equally useful if kept in
 combination either with fixed air or with water;
 in which states the quantities may be more accu-
 rately ascertained by weight when used, than if
 pure; because their rapid attraction for water, in

ALKALIS. the latter case, renders the weighing almost impracticable.

Alkalis which contain fixed air, are called mild alkalis.

Alkali of nitre,
called fixed
nitre.

For very nice purposes this alkali may be had from common nitre by deflagration. Nitre consists of the alkali united with an acid. If the finest prismatic nitre be fused, and made red-hot in a crucible, and charcoal be then added by degrees, a most intense combustion takes place, during which the acid principle of the salt is dissipated, and the alkali is left in combination only with fixed air. More charcoal must be added, as long as it continues to produce the vivid flame; and the heat must be raised towards the end, in order that the decomposition of the last portions of the nitre may be more completely effected. This salt has been improperly called fixed nitre; but there is no difference between the pure specimens of this alkali, whatever subject it may have been originally obtained from.

Purification of
fixed alkali.

Fixed alkalis may be had in a state of great purity by treatment with ardent spirit*. The alkali is first to be deprived of most of its fixed air by boiling, with about its own weight of quicklime, in twelve parts of water; and the clear solution must then be evaporated till it begins to be slightly consistent. It must then be mixed with the strongest ardent spirit; and part of the spirit may be drawn off by distillation. As soon as the retort has become cold, it is found to contain a solution of pure alkali in ardent spirit, which floats

* Berthollet, in the Journal de Physique for 1786.

above

above another aqueous fluid, containing that part of ALKALIS.
 the alkali in crystals which still retains its fixed air,
 and also the earthy or metallic impurities of the
 alkali. The spirituous solution being decanted off,
 and evaporated on a sand bath, affords crystals of pure
 alkali in groups of quadrangular pyramids, which are
 very deliquescent, and soluble both in water and ardent
 spirit, with the production of cold.

The vegetable alkali, in its usual state, deliquesces Oil of tartar.
 in the air, and consequently unites with water in all
 proportions. The strong solution of this alkali is
 usually called oil of tartar per deliquium. Its action
 on the skin produces a sensation or feel of greasiness,
 which has given occasion to this appellation. But it
 may be had in permanent crystals, if enough of fixed
 air be added to its solution.

The mineral alkali in its obvious properties differs Mineral alkali.
 but little from the vegetable. Its attractions in gene-
 ral are less strong, and the compounds it forms with
 other bodies are very different from those produced
 with the vegetable alkali. It usually contains enough
 of fixed air to render it much less attractive of water
 than salt of tartar. If the quantity of water containing
 salt of soda be diminished to about two and a half times
 the weight of the salt; this last begins to separate in
 crystals, which do not deliquesce in the air, but become
 dry, and fall to powder, by the loss of that portion of
 water which entered into the formation of the crys-
 tals.

The water which enters into the formation of the Water of crys-
 crystals of any salt, is called the water of crystalliza- tallization.
 tion; and such salts as fall to powder by exposure to Efflorescence.
the

ALKALIS. the air, are said to effloresce: the pulverulent substance thus obtained is sometimes called an efflorescence.

Abundance of
mineral alkali;
in sea salt,

Mineral alkali abounds in vast quantities in the waters of the sea, where it forms half the weight of the common salt; and it is sometimes found in other natural combinations. The efflorescence, or saline matter, which hangs upon old damp walls, consists of this salt united to fixed air and water; and in many places in Asia and Africa it is collected at the surface of the earth.

→ obtained by
incineration.

The mineral alkali in trade is obtained by burning certain plants which grow on the sea shore. It contains several neutral salts in small proportions, which may be separated by crystallization; as the alkali, being the most soluble, remains suspended in water longer than the rest. Sea salt may be decomposed, and its alkali obtained alone, but not sufficiently cheap for common uses. Mr. Turner's process is said * to consist in mixing a quantity of litharge (or calcined lead) with half its weight of common salt; which, after trituration with water till it assumes a white colour, is left to stand some hours: after which a decomposition ensues, the alkali becoming disengaged with water, while the acid unites with the metallic calx. This last, by a proper degree of heat, produces a fine greenish yellow pigment, the sale of which is the chief object of the manufacturer.

Turner's pro-
cess with
common salt.

The fixed alkalis are still considered as simple substances with regard to the present state of our knowledge. It is suspected however that the fixed vegeta-

* Cronstedt's Mineralogy, by Magellan, vol. i. p. 336.

ble alkali may consist of lime in combination with the substance called phlogisticated air; and that the mineral alkali is composed of magnesia, united to the same substance. The reasons for these suppositions are:
 * A small quantity of common nitre is produced by exposing washed chalk for some months to the exhalations of putrid animal substances. The repeated distillation of soap affords volatile alkali, and this contains phlogisticated air. And a portion of magnesia has been obtained by repeated solutions and calcinations of mineral alkali.

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Fixed alkalis, deprived of the fixed air they may contain, by boiling them for a short time with quicklime, which has a stronger attraction to the air, and becomes converted into chalk by the process, are then said to be caustic, because they act with such energy as to corrode and destroy animal substances. Soap —or soap lees, is a solution of this kind; and the combination of a caustic alkali with fat, or oil, is well known by the name of soap. If one part of lime, and two of salt of soda, be boiled in twelve parts of water for a short time, and the filtered lixivium be evaporated till its specific gravity be about 1.375, or, which is the same thing, till a phial which would contain an ounce of water would contain an ounce and three eighths of the solution; the soap may be made by mere mixture of this lye with olive oil, in the proportion of one part of the former with two of the latter, in a glass or stoneware vessel. This mixture, being beat up from time to time with a wooden spatula, soon becomes consistent;

Caustic solution of alkali :

Soap,

* Thouvenel on Nitre. Chaptal's Elements of Chemistry, i, 181. Eng. transl, and the authors by him cited.

and

ALKALIS. and in seven or eight days it forms a very white and hard soap.

Manufacture of soap in the large way. In large manufactories the lye is made no stronger than to float an egg, when the workmen begin to form the mixture. To a part of the lye diluted they add an equal quantity of oil, which is set on a gentle fire, and agitated. When the combination begins to take place, the rest of the lye is added, and the whole digested by a gentle heat till the soap is formed. If well made, it is firm and white, and completely mixes with water, without exhibiting any grease on the surface. Trials are made of it during the boiling; and the requisite additions, either of oil or alkali, are made as circumstances require.

Manufacture of glass. That beautiful product of human industry, glass, consists of siliceous earth dissolved in an alkali. For this purpose, nothing more is necessary than to expose a proper mixture of sand, flint, or crystal, and fixed alkali, to heat in a furnace till they are incorporated together by fusion. Simple however as this process may appear, it is by no means an easy operation to make a perfect glass. If the materials be impure, and contain either metallic particles, or such as cannot be vitrified, the glass will be coloured, or defaced with opake specks. If the proportion of alkali exceed two parts to one of earth, the glass will be liable to alteration by the action of the air or saline substances, especially acids. If the fusion be not continued a sufficient time, the glass will be imperfect for want of a sufficient combination of the materials; and no means have yet been found to prevent the lower part of the pots of glass from containing a denser glass than the upper,

upper, by the subsidence of the heavier materials; a circumstance which produces the appearance of threads or veins in the work, on account of the different action of the several parts of the same glass on the rays of light. The management of the heat is also a material point; for every increase of heat extricates bubbles of some elastic substance; and if the glass be used during this effervescence, it will abound with little cavities which injure its transparency. The imperfections of glass are most sensibly felt in the construction of optical instruments, especially those which are called achromatic.

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To prevent the swelling, at the first combination of the materials, they are previously mixed, and exposed for a considerable time in a lower heat than is sufficient to convert them into glass; by which management great part of the more volatile matters is dissipated. This imperfect combination is called frit, and is afterwards fused by a stronger heat. Glass utensils, unless very small, require to be gradually cooled in an oven. This operation is called annealing; and is necessary to prevent their cracking by change of temperature, wiping, or slight accidental scratches.

Frit.

The volatile alkali is most commonly obtained from sal ammoniac. This salt was formerly imported from Egypt, where it is procured by sublimation from soot produced by burning the dung of camels. It is now made in great plenty for the purposes of trade in Great-Britain. The component parts are volatile alkali, and the same acid as enters into the composition of sea salt, and is called the marine acid. The volatile alkali is obtained in an impure liquid state by the manufac-

Manufacture of
sal ammoniac.

turers,

ALKALIS. turers, who distil it from bones, or foot, or any other substance that affords it. To this they add the vitriolic acid, and also common salt, in due quantities. The vitriolic acid first combines with the volatile alkali; but when the common salt, which consists of fixed mineral alkali and marine acid, is added, a change of the principles takes place by double elective attraction. The vitriolic acid seizes the mineral alkali, and forms the new compound known by the name of Glauber's salt; while the marine acid unites with the volatile alkali, and forms sal ammoniac. By evaporation of the water, these salts are separated by crystallization, and the sal ammoniac is sublimed into cakes for sale.

Volatile alkali : In order to disengage the volatile alkali from sal ammoniac by distillation, it is necessary to add some fixed substance which shall combine with and prevent the marine acid from rising. Chalk and slaked lime are the bodies commonly used. If a mixture of two parts of chalk, and one of sal ammoniac in powder, be exposed to a sand heat in a retort, with a receiver adapted, a change of principles by double affinity takes place. The chalk, which consists of lime and fixed air, is decomposed, and also the sal ammoniac. The lime unites with the marine acid, and forms a fixed earthy salt, which remains in the retort; and the fixed air unites with the volatile alkali, and passes into the receiver, where it appears in the form of a white hard salt of a pungent smell. This is the mild volatile alkali, or sal volatile of the apothecaries and perfumers. It is well known as a stimulant usually put into smelling-bottles.

—obtained by
the medium of
chalk :

When lime, or calcareous earth deprived of fixed ^{ALKALIS.} air, is made use of, the decomposition takes place as ^{—obtained by the medium of lime.} before; but the volatile product has a very different appearance. It consists, for the most part, of a permanently elastic or aërial fluid, which very readily combines with water, but may be confined in its elastic state in vessels over mercury. Most of this product was formerly lost, because no more of it was detained in the vessels than had combined with the water which was driven over by heat from the materials in the retort. But by the use of an apparatus upon the principle of fig. 21, the air may be received and absorbed by water, without that great loss which must have arisen from the aërial fluid rising long before the water, and the quantity of this last being insufficient to retain it.

This permanently elastic fluid is called alkaline air, ^{Alkaline air.} and consists of the pure volatile alkali itself. If fixed air be added to it, a white cloud is formed, consisting of mild volatile alkali, which precipitates; and the airs are either diminished or disappear, according to their relative proportions to saturate each other, or their respective degrees of purity. With the marine acid air, hereafter to be treated of, which is the pure marine acid, it forms sal ammoniac in the same manner. It unites with equal readiness with the other acid airs. With water it forms the fluid volatile alkali commonly called spirit of sal ammoniac with lime.

The volatile alkali is decomposed and formed again ^{Decomposition and formation of volatile alkali.} in many chemical processes. These, generally speaking, require a more intimate knowledge of chemical

facts

ALKALIS.

facts than the reader can yet be supposed to possess, for them to be spoken of at length in this place. It will therefore be sufficient to observe, that the dimensions of alkaline air are greatly enlarged by repeatedly passing the electric spark or explosion * through it, or by igniting a piece of earthen ware in it; and it is by this means rendered incapable of being absorbed by water, and becomes inflammable. By the admission of vital air, and detonation, the inflammable part is condensed, and the remainder is found to be phlogisticated air †. Hence, as well as from other experiments, it is concluded that alkaline air consists of four parts by weight of phlogisticated, and one of inflammable air.

Characters of acids.

Acids are a genus of salts, which may be considered as less simple than the fixed alkalis; because there are experiments which clearly shew that they may be decomposed into principles still simpler. Their properties are—1. They change the blue vegetable colours of syrup of violets, or tincture of litmus, to a red. 2. Their taste is sour, and in general corrosive, unless diluted. 3. Most of them unite with water in all proportions; and many have so strong an attraction for it, that they cannot be exhibited in the solid state. 4. They combine with alkalis by a stronger affinity than is possessed by most other substances to those salts at a moderate temperature. 6. They act upon earths, and upon most inflammable substances and metals.

* Priestley, ii. 239. v. 218. vi. 189.

† Berthollet in Mem. Acad. Par. for 1785, page 324. Also Austin in Phil. Trans. vol. lxxviii. p. 387.

The acids found in the mineral kingdom are—the vitriolic acid, known in commerce by the name of oil of vitriol; the nitrous acid, called spirit of nitre; the marine acid, called spirit of salt; the aërial acid, or fixed air; the acid of borax, called sedative salt; the acid of spar, or sparry acid; succinous acid, or acid of amber; the acid of phosphorus, or phosphoric acid; the acid of tin; the acid of arsenic; the acid of molybdena; the acid of tungsten, or of wolfram.

ACIDS.

Enumeration.
Mineral acids.

The vegetable kingdom affords the acids of lemons; of apples, or unripe fruits; of galls; of benzoin; of tartar; of sugar, or sorrel; the empyreumatic acid of tartar; the empyreumatic acid of sugar, or mucilage; the empyreumatic acid of wood; the acid of camphor; the acid of cork; and the acetous acid, or vinegar.

Vegetable
acids.

The animal kingdom affords the acid of milk; the acid of sugar of milk; the acid of ants; the acid of Prussian blue; the acid of fat; the acid of the stone of the bladder; and the acid of silkworms.

Animal acids.

When an inflammable substance is added to a strong acid, the effects in general are, that the acid is rendered more volatile, and part flies off in an elastic form, which has various properties, according to the nature and properties of the acid, as will be hereafter shewn.

Inflammable
additions to
acids.

In the theory of phlogiston, acids are supposed to contain that principle, and to be capable of uniting with it in various proportions. When they have received a larger proportion, they are rendered more volatile, and fly off in the elastic form; and when

Theory.

ACIDS.

Theory.

they have a less than the usual proportion of it, they are said to be dephlogisticated, and act more strongly on phlogistic bodies. In the new theory, acids are supposed to consist each of a peculiar base united to vital air in a fixed state. If they act on a combustible body, and become deprived of part of their vital air by its action, their constitution is changed, and their base is more disposed to fly off; but if by any means they obtain an over-proportion of vital air, their action on combustible bodies is more efficacious.

Vital air a
component
part of acids.

Most of the phlogistian chemists admit of the existence of vital air, as a component part of acids; a position which seems indeed to be as well established upon facts as any part of the science of chemistry.

Neutral salts.

Combinations of alkalis with acids are called neutral salts.

C H A P. IX.

OF METALLIC BODIES IN GENERAL.

METALLIC substances are very easily distinguished from all other bodies in nature, by their very great weight, and that opaque shining appearance which is called the metallic splendour or brilliancy. Very few substances have half the specific gravity of the lightest among the metals. They are all fusible, though at very different temperatures; and if the fusion be made in close vessels, they fix again by cold, without having suffered any change but that of external figure, which must be produced in all bodies which have been either liquefied or volatilized; namely, they assume the form of the vessel which contains them. Some of them may be extended considerably by the hammer, without breaking them. This property is called malleability; and the metallic bodies which possess it are called entire metals, or metals, in contradistinction to such as are more brittle, and are called semi-metals. Metallic substances are also called perfect and imperfect. The perfect are such as undergo no lasting change of their properties by any heat we can apply to them, at least in common furnaces. The imperfect metals, when exposed to a strong heat, with access of vital air, are changed, by a process similar to burning, and in some of them with an actual flame, into a brittle dull substance called a calx, which is heavier than the metal it came from, though its specific gravity is not

CHARACTERS
OF METALS.

Entire metals.

Perfect and im-
perfect metals.

Calces.

**METALLIC
SUBSTANCES.**

Acids.

so great. Some are even converted into acids. If the calx of a metal be exposed to strong heat in a closed vessel, with some inflammable matter, it recovers its metallic state. This is called reduction or reviving of the metal.

**Enumeration
of metals.**

All metals are imperfect except gold, silver, and platina. The imperfect metals are, mercury, lead, copper, iron, and tin; and the semi-metals are, bismuth, nickel, arsenic, cobalt, zinc, antimony, manganese, wolfram, molybdena, and uranite. The names arsenic, antimony, manganese, wolfram, and molybdena, being used to denote the mineral substance from which the semi-metals are obtained, the semi-metals themselves are distinguished by the name of regulus of arsenic, regulus of antimony, and so forth; though modern chemists often use the simple term to denote the semi-metal itself alone.

Regulus.

**Freezing point
of metals.**

Metals, like other fusible bodies, have each a fixed temperature, or freezing point, at which they become solid. They assume a crystallized figure in cooling, which is different in each, and may be seen by fusing them in melting-pots with a hole in the bottom, stopped with a stopper; for in this case, if the surface be suffered to congeal, and the fluid metal beneath be suffered to run out through the hole, the under surface of the remaining metal will be curiously crystallized. The specific gravity of metallic substances is very considerably affected by the gradual or hasty cooling, or transition from the fluid to the solid state. Hammering renders them harder and more elastic; but this effect is destroyed by ignition.

Crystallization.

Affinities.

The affinities of metals to each other are various.

Some

Some will not unite at all ; others mix very readily, and even combine together. On this property is founded the art of soldering ; which consists in joining two pieces of metal together by heating them, with a thin piece or plate of a more fusible metal interposed between them. Thus tin is a folder for lead ; brass, gold, or silver, are folders for iron, &c.

METALLIC
SUBSTANCES.

Solders.

Mountainous districts, where the surface of the globe has been thrown up or disturbed, in remote ages, by earthquakes, volcanos, or other great convulsions of nature, are the most abundant in metallic bodies. In digging into the bowels of the earth, the various materials are mostly found disposed in strata or beds, which in plains lie level, but in mountains are inclined ; whence it happens that in mountainous countries some strata are often exposed to the day, which would else have been too deeply lodged to be come at by human art. It is in the stratified mountains that metals are usually found, mostly in a state of combination either with sulphur or arsenic, or in the state of a calx. They are also found, though less frequently, in the metallic or native state.

Countries most
abundant with
metals.

The combinations, or earthy bodies, which contain metals in sufficient quantity to be worth extracting, are called ores. Iron ore sometimes forms entire mountains ; but in general the metallic part of a mountain is very inconsiderable in proportion to the whole. The ores run either parallel to the stony strata, though far from having the same regularity of thickness, or they cross the strata in all directions. These metallic strata are called veins. The cavity formed by art in the earth, for the extraction of metals or any other mineral bodies,

Ores. Veins.
Mines. Matrix.

METALLIC SUBSTANCES. dies, is called a mine. The stone wherein a metallic ore is usually bedded, is called its matrix. These are not peculiarly appropriated to any metal, though some stones more frequently accompany metals than others.

Operations for
extracting me-
tals from ores.

The general operations by which metals are obtained from ores are—1. The minerals are selected; and such only are taken as from experience are known, by the external figure or appearance, to contain metal. 2. They are reduced to powder; and the lighter parts washed away, by means of water, in a shallow trough. 3. The volatile parts are dissipated by the operation called roasting. 4. The ores are smelted by throwing them into the midst of the fuel of a furnace, with earthy substances which are disposed to run into glass. In this operation, the glassy matter, called scoria, in some measure produces the effect of rendering the lower part of the furnace a closed vessel; and the fuel revives the metal, which in the ore is usually of the nature of calx. The revived metal being much denser than the scoria, falls to the bottom, and is suffered to run out by proper openings. These are the general operations, but they are not all necessary in all cases; and the particular practice with the several ores of each metal, must vary according to the properties of the metal itself, and the different substances it is united with.

Affaying, or
essayng.

The extraction of metals from ores, in the small way, which is necessary to be made in order to ascertain whether the specimens are worth working, is called affaying or essayng. In these small trials the fusibility of the pounded ore is increased by an addition of black flux, which is an impure alkali, formed
by

by mixing two parts of tartar with one of nitre, and setting them on fire. Metallic ores may be very accurately assayed by solution and precipitation in the humid way.

METALLIC
SUBSTANCES.

Humid way.

The theory of the calcination and reduction of metals, according to the system of phlogiston, is as follows:—Metals, like all other inflammable bodies, contain phlogiston united to a base. While the vital part of the air unites with the base, the phlogiston is disengaged, and leaves behind it the combination called a calx, which is heavier than the metal, because the air received exceeds the weight of the phlogiston disengaged.—In the antiphlogistic system, metals are considered as simple substances, which are converted into calces by their union with vital air, and are revived by heating them with any other matter which is more combustible than themselves; that is to say, which has a stronger attraction for vital air, at the temperature of reduction. Some of the maintainers of phlogiston admit that the vital air unites with that principle of inflammability, and composes a substance which combines with the base of the metal. Here the fact agrees with the statement of the antiphlogistians, but the explanation is less simple.

Theory.

Most metals will uniformly mix with each other; and the specific gravity of the compound is seldom such as would have been deduced from the supposition of a mere mixture, or simple apposition of parts. Their fusibility is likewise greatly changed by mixture, and according to no certain rule yet discovered.

Mixture of metals.

Mixtures of metals are frequently called alloys. But the word alloy, or allay, is mostly used to denote a

Alloys.

METALLIC SUBSTANCES. portion of metal which is added to the precious metals, gold or silver.

Solubility of metals in acids.

Metals are mostly soluble in acids, with which they form salts. When a metal is added to an acid, the general effect produced is the same as would have arisen from the addition of any other combustible substance to the acid. If an alkali or earth be added to a metallic solution, the metal falls to the bottom in the form of a calx. But if a metal which has a stronger affinity with the acid than the metal already dissolved has, be added to such a solution, the former metal will fall to the bottom in its metallic state, and the latter will be dissolved without causing any of the escape of elastic fluid, and other appearances, which would have taken place if it had been applied to the mere acid; notwithstanding which, the latter metal, if precipitated by an incombustible substance, such as an alkali or earth, will be in the state of a calx.

Inferences.

It is evident, from these facts, that the action of acids upon metals is similar to that of heat with access of vital air; and of course may be accounted for, upon both the theories of chemistry, in the same manner as combustion itself. According to the original theory, when an acid acts upon a metal, it unites with the base of the metal, and expels the phlogiston; which either rises alone, in the form of inflammable air; or, combining with the acid itself, forms an acid air, or volatile acid. If an alkali be added, the calx falls down, combined with air, which it obtains either from the alkali or the acid; but if a metal be added, the phlogiston of this last, uniting with the calx of the former, revives it, and it falls down in its metallic state. The new

Original theory.

theory

theory may be applied as follows: When a metal is added to an acid, it attracts vital air either from the acid itself or from the water. If the former, the acid itself is decomposed; and its base, combined with an under proportion of vital air, arises in the form of volatile acid, or acid air. But, if the latter, the water itself is decomposed, its vital air combining with the metal, and its inflammable air flying off: in this case, the acid is supposed to do nothing more than hold the calx in solution, and by that means facilitate the action of the water, which would be much less effectual if the calx were suffered, on account of its insolubility, to remain upon and defend the surface of the metal; which, by reason of its insolubility in mere water, it would not fail to do, if the acid were not present.

METALLIC
SUBSTANCES,
New theory.

Metals are precipitated by each other in the same order, or nearly so, in all acids. Hence it is inferred, that this effect is produced by the reaction of some common principle, either of the metal or of the acids. In the old theory, a metal which has a stronger attraction for phlogiston, will take that principle from another metal which holds it more weakly; and of course the latter will cause the former to be precipitated in its metallic form. In the new theory, a contrary transference of vital air from the acid produces the same effect: for if a metal has a stronger attraction for vital air than is exerted by another metal already in solution, it will deprive this last of it, and cause it to fall down in the metallic state.

Precipitation of
metals by me-
tals.

Acids dissolve metals only in their calciform state; and there is a certain limit near which the solution is

Limit of solu-
tion in acids.

best

METALLIC
SUBSTANCES.

Theory of so-
lution.

best performed. If an acid be of such a nature as to be incapable of calcining a metal, it will not dissolve it, though the same acid would dissolve the calx if presented to it; and if the calcination be carried on too far, the calx will likewise be insoluble. To explain this according to the two theories, it may be observed, that acids calcine metals by virtue of their attraction for phlogiston, and suspend the calx by virtue of the same power exerted on the remaining portion of phlogiston, of which they cannot in general divest the calx; consequently, if the calx be divested of this portion, it will be insoluble. Or, in the other theory, the simple metal attracts as much vital air from the acid as is sufficient to convert itself into a calx, but not enough to saturate it with that principle: it is therefore suspended, in consequence of its remaining weak attraction for the vital air of the acid. But if the calcination be complete, that is to say, if the affinity of the metal for vital air be perfectly satisfied, the remaining attraction of the metal for vital air will cease, and it will be insoluble.

Action of va-
rious substances
on metals.

The direct action of alkaline salts upon metals is not considerable: sulphur combines with most of them readily in the way of fusion; and the combination of sulphur with an alkali, called liver of sulphur, is a powerful solvent of all metals except zinc. Nitre, heated with metals, acts in the same manner as it does with other inflammable bodies—it deslagrates, and the metals become calcined. The perfect metals resist the action of nitre.

B O O K II.

PARTICULAR CHEMISTRY.

SECTION II.

CONCERNING THE MINERAL ACIDS, AND
OTHER MINERAL BODIES WHICH ARE
CONVERTIBLE INTO ACIDS.

C H A P. I.

OF SULPHUR, VITRIOLIC ACID, AND THE COMBINA-
TIONS THEY FORM WITH OTHER BODIES.

SULPHUR, or brimstone, is a well-known hard, brittle, inflammable substance, of an opake yellow colour. It is found more or less pure in the neighbourhood of volcanos, where most probably it is always expelled from some previous state of combination by the heat of subterraneous fires. It is a very common ingredient in a great variety of minerals and ores; but it is extracted for sale chiefly from a stone called pyrites. This stone is often of an irregular glo-
bular figure; and, when broken, is found to have a radiated texture, the fibres usually converging towards a centre. Their great weight, and the shining golden colour

SULPHUR.

Pyrites.

SULPHUR.**Pyrites.****Distillation of sulphur :****—sublimation.****Action of water upon sulphur.**

colour of some specimens, often lead the ignorant to suppose them rich in precious metal. The contents of the pyrites are various ; but the kind here spoken of contains from one sixth to one third of its weight of sulphur, one eighth to five eighths iron in a calcined state, and the rest clay and siliceous earth. They give fire plentifully with the steel ; whence their name is derived. A moderate heat will expel the sulphur from pyrites, as it is considerably volatile. In the large way, in Germany and Italy, the pyrites are put into earthen cucurbits, disposed in a furnace in such a manner that when the sulphureous part melts, it runs into vessels filled with water, and there congeals.

Sublimation is necessary to deprive sulphur of the accidental impurities it may contain. This may be done in an earthen cucurbit set on a sand bath, with a head properly adapted. The sulphur rises by a very gentle heat, little more than is sufficient to melt it ; and the fine sublimate thus obtained is called flowers of brimstone.

Water has no immediate action on sulphur. It is said, however, to soften the outside by long contact with it ; and if sulphur be heated nearly to such a degree as to set it on fire, and then poured into water, it becomes soft, and partly transparent. In process of time it recovers its original hardness and opacity. If steam of water be passed over sulphur contained in a heated earthen tube, inflammable air is extricated either from the sulphur or the water, and comes out at the end of the tube*. The experiment is troublesome on account of the sulphur subliming.

* Priestley, vi. 150.

The combinations of sulphur with earths or alkalis are called hepars, or livers of sulphur, from their colour. There is no perceptible action between sulphur and siliceous earth. Argillaceous earth has very little action upon it in the direct way; but lime unites readily with it. If fresh quick-lime and flowers of sulphur be mixed, and water be added a little at a time, the heat of the lime will be sufficient to produce the combination. On addition of more water, it becomes reddish, and emits a fetid smell of rotten eggs, which is common to all the hepars. The more caustic the lime, the deeper the colour of the hepar. The pure fixed alkalis decompose calcareous hepar, by virtue of their stronger affinity to the sulphur: and any acid whatever decomposes it, by attracting the lime; the sulphur at the same time falling to the bottom in the form of a subtle powder, formerly called magistery of sulphur.

SULPHUR.

Combination
of sulphur :
with lime :

Pure ponderous earth boiled in water with sulphur, has but little action upon it: but in the dry way, when ponderous spar, or the combination of vitriolic acid and ponderous earth, is strongly heated in a crucible with charcoal, a coherent mass is formed, which is soluble in water, with the smell and other hepatic characters; and if any acid be added which will form a soluble salt with the ponderous earth, a precipitate of sulphur will be obtained.

—with ponderous earth :

If a small quantity of magnesia, and an equal quantity of flowers of sulphur, be inclosed in a vessel perfectly filled up with distilled water, and well stopped, and then exposed to heat by immersion in boiling water for several hours, a combination will take place, and

—with magnesia.

SULPHUR. and the water will contain a magnesian liver of sulphur; from which the earth may be precipitated by the addition of an alkali, which will unite with the sulphur; or the sulphur may be precipitated by an acid, which will combine with the earth.

**Combination
of sulphur with
fixed alkalis.**

The fixed alkalis combine very readily with sulphur, either in the moist or dry way, whether they be in a pure or caustic state, or combined with fixed air; though more strongly in the former than the latter case. If a solution of fixed alkali in water be boiled with half its weight of powdered sulphur, a combination takes place, and liver of sulphur is formed. Or, if equal parts of dry alkali and powdered sulphur be melted in a crucible, and poured out on a flat polished stone, as soon as the fusion is complete, the combination will be of a liver colour, and is the solid hepar. If it be made with a pure or caustic alkali, its colour is deeper, and its characteristic properties more intense, than when a mild alkali is used. A solution of the solid hepar in water forms precisely the same substance as the preparation made in the moist way.

Hepatic air.

The peculiar fetid smell of the solid hepar when moistened, or of its solution, is produced by the emission of a permanently elastic fluid, called hepatic air. This smell, when strong, is insupportable, and suddenly destroys animal life. Hepatic air is very soluble in water, which it converts into a state perfectly resembling that of the sulphureous mineral springs. It renders syrup of violets green, blackens the calces of lead and bismuth, and the surface of silver. Vital air decomposes it, and causes sulphur to be deposited. It
detonates

detonates with vital air when set on fire. It is not SULPHUR.
 clearly ascertained in what manner the sulphur is suspended in hepatic air. Sulphur, melted by the burning glass, in inflammable air over mercury, produces a fluid which has the properties of hepatic air; and Hepatic air.

* if inflammable air be passed through melted sulphur, it becomes converted into hepatic air. As this air is not obtained from hepar unless water be present, it has been supposed to consist of sulphur volatilized, in combination with inflammable air, extricated by a decomposition of the water; whose other component part, namely, vital air, is supposed to unite with the sulphur. It is even asserted that the residue contains vitriolated tartar.

Fluid volatile alkali has very little action on sulphur; but a volatile hepar may be produced by the union of alkaline air with sulphur in the vaporous state. If equal parts of quick-lime and sal ammoniac be mixed together with half a part of sulphur, and distilled with the pneumatic apparatus (fig. 15 and 21), with a small quantity of water in the receiver, a reddish yellow hepatic liquor will be obtained, which is the volatile hepar, and was formerly known by the name of the fuming liquor of Boyle; so called from its inventor, and from the white fumes it emits in the air. Volatile liver of sulphur.

Sulphur combines with most metallic bodies in the dry way. Oils likewise dissolve it, and form compounds called balsams.

* Hassenfratz in Phil. Trans. vol. lxxvii. p. 306.

When

SULPHUR. When sulphur is heated in an open vessel, it melts; and soon afterwards emits a blueish flame, visible in the dark; but which, in open day-light, has the appearance of a white fume. This flame has a suffocating smell; and has so little heat that it will not set fire to flax, and may even be suffered to play against the palm of the hand without any considerable inconvenience. In this way the sulphur may be entirely consumed. If the heat be still augmented, the sulphur boils, and suddenly bursts into a much more luminous flame; the same suffocating vapour still continuing to be emitted.

Combustion of sulphur.

Volatile vitriolic acid. The suffocating vapour of sulphur is imbibed by water, with which it forms the fluid called volatile vitriolic acid. If this fluid be exposed for a time to the air, it loses the sulphureous smell it had at first, and the acid becomes more fixed. It is then the fluid which was formerly called spirit of vitriol. Much of the water may be driven off by heat; and the dense acid which remains is the vitriolic acid, commonly called oil of vitriol: a name which was probably given to it from the little noise it makes when poured out; and the unctuous feel it has when rubbed between the fingers, produced by its corroding and destroying the skin, with which it forms a soapy compound.

Oil of vitriol.

Vitriol of iron. The pyrites before mentioned, which consist, for the most part, of sulphur and iron, are found to be converted into the salt called vitriol of iron by exposure to air and moisture. In this natural process the pyrites break, and fall in pieces; and if the change take place rapidly, a considerable increase of temperature follows, which is sometimes sufficient to set the mass

mass on fire. By conducting this operation in an accurate way, it is found that vital air is absorbed. The vitriol is obtained by solution in water, and subsequent evaporation; by which the crystals of the salt are separated from the earthy impurities which were not suspended in the water. SULPHUR.

The vitriolic acid was formerly obtained by distillation from vitriol of iron. When this salt is exposed to heat, the vitriolic acid comes over, at first attended with a large quantity of volatile sulphureous vapour; and, towards the end, there is a production of pure dephlogisticated air. The acid which rises last has a concrete crystalline form. The acid obtained in this process is black, and requires to be purified by a second distillation, or rectification, in which the volatile sulphureous acid comes over, and leaves the dense vitriolic acid behind. Distillation of vitriol.

Most of the vitriolic acid now used is produced by the combustion of sulphur. There are three conditions requisite in this operation. Vital air must be present, to maintain the combustion; the vessel must be close, to prevent the escape of the volatile matter which rises; and water must be present, to imbibe it. For these purposes, a mixture of eight parts of sulphur with one of nitre is placed in a proper vessel, inclosed within a chamber of considerable size, lined on all sides with lead, and covered at bottom with a shallow stratum of water. The mixture being set on fire, and shut up, will burn for a considerable time, by virtue of the supply of vital air which nitre gives out when heated; and the water, imbibing the sulphureous vapours, becomes gradually more and more acid, after repeated

L

com-

VITRIOLIC ACID. combustions ; and the acid is afterwards concentrated by distillation.

Characters of vitriolic acid.

Pure vitriolic acid is colourless, and emits no fumes. It strongly attracts water, which it takes from the atmosphere very rapidly, and in large quantities, if suffered to remain in an open vessel. If it be mixed with water, it produces an instantaneous heat, nearly equal to that of ebullition. Its action upon all the earths except the siliceous, upon the alkaline salts, upon many metals, and almost every other combustible substance, is very strong.

Combination of vitriolic acid and clay.

With argillaceous earth it forms alum. This well-known salt has a peculiar austere or astringent taste ; is soluble in about fifteen times its weight of water, at the temperature of 60° , and in a much less quantity at higher temperatures ; from which it may be separated in the form of permanent crystals. It fuses at a moderate heat, and froths up till its water of crystallization is evaporated ; at which period it has the form of a white friable substance, called calcined alum, which retains the greatest part of its acid when not too much heated ; and may again be restored to its original form by adding the water it had lost by the heat.

Preparation of alum.

Alum is not made for the purposes of commerce by a direct combination of the vitriolic acid and clay, but is extracted from substances usually called alum ores, which either are, or probably were originally, composed of clay and sulphur. From such as contain the alum ready formed, as is the case with earths of this kind found in the neighbourhood of volcanos, it is extracted by lixiviation in water, and subsequent evaporation. But other substances, such as pyrites and
alum

alum slates, require to be burned or exposed to the air and moisture for a time, before any alum can be had from them. These processes convert the sulphur into vitriolic acid. Alum works have long been established in Britain, and many other parts of the world.

VITRIOLIC
ACID.

The acid in alum is not saturated. If a solution of alum be boiled upon clay, a considerable portion of the latter will unite with the salt, and form a combination which is much less soluble than the alum itself.

With calcareous earth the vitriolic acid forms gypsum, or plaster of Paris. This saline substance is plentifully found in nature; and is known by different names, according to its texture and external appearance. The lapis specularis and alabaster are of this kind. It requires about five hundred times its weight of water to dissolve it at the temperature of 60° , and has for that reason been reckoned an earth. Its chief use has been already adverted to.

Vitriolic acid
with lime,
p. 104:

With ponderous earth the vitriolic acid forms the ponderous spar, or marmor metallicum.

—with ponderous earth,
p. 105:

With magnesia it forms Epsom salt, which has a bitter taste. This is soluble in its own weight of water, at the temperature of 60° ; and by evaporation it is recovered in crystals, which are disposed to effloresce, or become converted into a dry powder by exposure to air.

—with magnesia, p. 106:

With the vegetable alkali this acid forms a salt commonly called vitriolated tartar, which is soluble in about sixteen times its weight of water, at the temperature of 60° ; and from which it may again be recovered by evaporation in the form of permanent crystals.

—with vegetable alkali.

VITRIOLIC
ACID.

Vitriolic acid
with mineral
alkali :

With the mineral or marine alkali, the vitriclic acid forms Glauber's salt, which requires only three times its weight of water to dissolve it at the same temperature. It is more soluble in hot than cold water; and may therefore be separated from a hot saturated solution, either by cooling or by evaporation. Its crystals are usually large and well formed; but they lose their water of crystallization, which amounts to near half their weight, by exposure to the air, and fall into an efflorescence, or white powder.

—with volatile
alkali :

The combination of the vitriolic acid with volatile alkali, is called vitriolic ammoniac. It is soluble in twice its weight of cold or an equal weight of hot water; and affords crystals either by cooling or evaporation, which are permanent, or slightly disposed to attract moisture and deliquesce. Some chemists assert that it is volatile, and others affirm the contrary. Upon examination, it would probably be found that the acid or alkali, or both, are decomposed by heat.

—with com-
bustible mat-
ter.

When any combustible substance is added to the concentrated vitriolic acid, the fluid becomes black; and emits white vapours, which are of an exceedingly pungent sulphureous smell; and, if received over mercury, are found to consist of a peculiar æriform fluid, which is not condensable into the fluid state except by a very great degree of cold*. It is soluble in water, which it converts into volatile vitriolic acid, of exactly the same nature as that obtained by the combustion of sulphur. Whence it follows, that the fumes of sulphur consist of this kind of air, rendered visible by

Æriform vitri-
olic acid.

Page 138.

* This was effected by M. Monge. See Fourcroy's Chemistry, vol. i. p. xxxi.

the moisture it meets and combines with in the atmosphere. Boiling vitriolic acid acts upon most metals, and affords vitriolic acid air, and with some of them sulphur; but with such metals as it can act upon when considerably diluted, it affords inflammable air. When this acid is distilled from metals to dryness, the latter product is vital air.

VITRIOLIC
ACID.

The sulphureous or volatile vitriolic acid forms saline combinations with earths, alkalis, and metals; but its attraction to these bases is much less than that of the vitriolic acid. Exposure to the air for a length of time changes these salts into common vitriolic salts, in the same manner, doubtless, as it changes the sulphureous acid into the common vitriolic acid.

Sulphureous
acid.

Vitriolic acid air is heavier than common air; and, like every other permanently elastic fluid, except vital air and its compounds, it extinguishes combustion, and destroys animal life. If alkaline air be mixed with it, the airs combine, and form a beautiful white cloud, which becomes condensed, and is found to be vitriolic ammoniac; at the same time that a yellow substance is separated, which seems to be sulphur. Water impregnated with this air may be frozen without parting with it; and if such impregnated water be exposed to heat for many days in a glass vessel hermetically sealed (that is to say, closed by melting its aperture with a blow-pipe), it deposits sulphur*.

Characters of
vitriolic acid
air.

The conversion of sulphur into the vitriolic acid, and contrary-wise, of the acid into sulphur, being effects of great importance in chemical theory; it became a desirable object to perform the latter, in order

Vitriolic acid
converted into
sulphur.

* Priestley, iv. 124.

VITRIOLIC
ACID.

Stahl's experi-
ment for ob-
taining sulphur
from vitriolic
acid.

to confirm such reasoning as was adopted respecting the former. As it is evident that sulphur becomes vitriolic acid by combustion, it must follow by analogy, from what happens in the revival or reduction of burned metals, or metallic calces, that sulphur might be revived from vitriolic acid, by exposing it to heat with some more combustible substance. A difficulty however presented itself in this attempt, which was, that the vitriolic acid, being rendered volatile by the addition of a combustible body, would elude the attempt to expose it to a considerable heat. This, no doubt, was the circumstance that directed the attention of the great founder of the theory of phlogiston (Stahl) to the neutral salts; in which the acid is not only highly concentrated, but combined with a more fixed body, namely, the alkali. He fused equal parts of fixed alkali and vitriolated tartar in a crucible; to which he added half a part of powdered charcoal. This mixture being well stirred together, and heated strongly for a very short space of time, was poured out, all sparkling, upon a smooth stone previously greased. The compound, when cooled, was found to be a true liver of sulphur; from which, after solution in water, and precipitation by adding an acid, the sulphur was obtained.

Electricity.

When the electric spark passes between two surfaces of vitriolic acid confined in a bended glass tube, there is a production of vital air.

Recapitulation
and theory.

Such are the principal facts relating to sulphur and the vitriolic acid; which, when considered with a view to theoretical arrangement, are found to be more immediately connected than at first view they may seem

to

to be. The combustion of sulphur is of the same nature as every other combustion. Vital air is absorbed, and the inflammable principle is supposed to be extricated. The sulphur, thus deprived of its phlogiston, and united to vital air, becomes an acid; which is not completely changed until, by subsequent exposure to the common air, it has imbibed still more of the vital part, and the remaining phlogiston has been dissipated. The decomposition of pyrites is a phenomenon of the same kind, but is performed more gradually, and of course with the accumulation of less heat. The sulphur of these combinations attracts the vital part of the air by an action which is supposed to be increased by the strong tendency of the iron to combine with the acid that results from the union; the phlogiston being dissipated for the same reason. Instead, therefore, of a combination of iron and sulphur, they become converted into vitriol, in which an acid is found: and as this process consists of the absorption of vital air, and disengagement of phlogiston, it is a true combustion; with this only modification, that the heat is seldom extricated so rapidly as to produce the appearances of ignition and flame, but is conducted off by the surrounding bodies nearly as fast as it is generated.

VITRIOLIC
ACID.

Theory.

Decomposition
of pyrites.

In the distillation of vitriolic acid from vitriol of iron, the acid is rendered black and sulphureous from the iron, which was not completely dephlogisticated or calcined during its original combination with the acid: for the phlogiston of the iron is supposed, in this distillation, to unite with the acid, and form sulphur; while the portion of the vital air which con-

Black vitriolic
acid.

VITRIOLIC
ACID.

Theory.

tributed to convert that sulphur into acid, unites with the calx, and is afterwards driven off towards the end of the process. A crystalline or concrete form of the acid is sometimes produced by its holding the vitriolic acid air in solution. If this be driven off by heat, the acid will be pure. Hence it is clear that the volatile vitriolic acid differs in fact from the pure vitriolic acid, in the circumstance that it holds sulphur in solution. And the vitriolic acid air is the same acid with sulphur, but with much less water, if any.

Mutual action
of vitriolic acid
and combusti-
ble bodies.

The change in the vitriolic acid produced by the addition of a combustible substance, is explained with equal facility; for it is the reverse of the inflammation of sulphur. The pure air of the acid is absorbed by the combustible body; while the phlogiston of this last unites with the base of the sulphur, and forms sulphur. This sulphur renders the acid volatile; and it comes over in the aerial form, together with water. If the combustible body be of such a nature as to leave a fixed residue, to which the last portions of acid may unite after all the water is dissipated, sulphur will come over alone. Or if all the sulphur be driven off, either with the water or after it, the last product will consist of the vital air which adhered to the residue, or fixed calx of the combustible body. When the diluted vitriolic acid acts upon a metal, and disengages inflammable air, the acid unites entirely, and without decomposition, to the calx, and the phlogiston flies off in the aerial form.

Liver of sul-
phur from vi-
triolated tartar.

An explanation nearly similar may be applied to the formation of liver of sulphur, when vitriolated tartar is fused with an alkali and charcoal. Vitriolated tartar,

consisting of vegetable alkali united to vitriolic acid, is decomposed by charcoal. This uniting with the vital air of the acid, at the same time that it communicates its phlogiston to the base, converts the acid into sulphur: the additional alkali serves only to assist the fusion of the original mass, and to prevent the dissipation of the sulphur by combining with it.

VITRIOLIC
ACID.

Theory.

Thus far we have admitted the inflammable principle in our explanation; and it must be admitted, if it can be shewn that sulphur contains it. We must confess however that this has not been proved; and that inflammable air has never been obtained directly from sulphur, except a small quantity, by passing steam of water over it when heated in an earthen tube*; in which case the original doubt presents itself, whether the air come from the sulphur or the water. The modern theory, which rejects phlogiston, accounts for the preceding facts simply by the absorption or extrication of vital air. Sulphur is taken to be a simple substance. The combustion of sulphur consists of the rapid combination of that substance with vital air; which, at the same time, gives out its heat as its capacity is diminished. A smaller proportion of vital air, with the sulphur, composes the volatile vitriolic acid, whether in the aerial form, or mixed with water: a larger dose forms the complete vitriolic acid. If a combustible body be added to vitriolic acid, this body becomes burned, or calcined, by uniting with part of the vital air of the acid; the remainder consequently has an over-proportion of sulphur, and therefore becomes volatile. If the absorption of pure air be suf-

Antiphlogistic
theory.

Page 95.

* Priestley, vi. 150.

ficiently

VITRIOLIC
ACID.

Theory.

ficiently copious, the acid is restored to its former state, and becomes sulphur again. When the combustible body is metallic, the pure air may, in some cases, be driven out by heat from the residue. And lastly, when inflammable air is obtained by the solution of metals in the diluted acids, it is taken for granted that it arises from the decomposition of the water, whose vital air, uniting with the metal, considered as a principal substance, calcines it; while the inflammable part flies off, and the acid does nothing more than dissolve the calx, and by that action facilitates its formation.

Detonation of
hepatic air.

The detonation of hepatic with vital air may be readily explained on either hypothesis; whether it be supposed to consist chiefly, if not entirely, in the combustion of the sulphur, which must by that means be suddenly converted into vitriolic acid air; or simply of the inflammable air, while the sulphur is deposited.

C H A P. II.

OF THE NITROUS ACID, ITS COMPONENT PARTS, AND
COMBINATIONS.

THE nitrous acid is obtained from the salt called nitre or salt-petre, which consists of the acid itself united to the vegetable alkali. This salt is never found in considerable quantities in nature, but is evidently produced by a concurrence of circumstances. The nitrous acid appears to be produced in all situations where animal matters are completely decomposed, with access of air, and of proper substances with which it can readily combine. Grounds frequently trodden by cattle, and impregnated with their excrements; or the walls of inhabited places where putrid animal vapours abound, such as slaughter-houses, drains, or the like, afford nitre by long exposure to the air. Artificial nitre beds are made by an attention to the circumstances in which this salt is produced by nature. Dry ditches are dug, and covered with sheds, open at the sides, to keep off the rain: these are filled with animal substances—such as dung, or other excrements, with the remains of vegetables; and old mortar, or other loose calcareous earth, this substance being found to be the best and most convenient receptacle for the acid to combine with. Occasional watering, and turning up from time to time, are necessary to accelerate the process, and increase the surfaces to which the air may apply. After a succession of many months, more or less, according to the management of the operation,

in

NITROUS
ACID.Production of
nitre.

Nitre beds.

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ACID.

in which the action of a regulated current of fresh air is of the greatest importance, nitre is found in the mass. If the beds contained much vegetable matter, a considerable portion of the nitrous salt will be common saltpetre; but, if otherwise, the acid will, for the most part, be combined with the calcareous earth.

Extraction of
saltpetre.

To extract the saltpetre from the mass of earthy matter, a number of large casks are prepared, with a cock at the bottom of each, and a quantity of straw within, to prevent its being stopped up. In these the matter is put, together with wood-ashes, either strewed at top, or added during the filling. Boiling water is then poured on, and suffered to stand for some time; after which it is drawn off, and other water added in the same manner, as long as any saline matter can be thus extracted. The weak brine is heated, and passed through other tubs, until it becomes of considerable strength. It is then carried to the boiler, and contains nitre and other salts; the chief of which is common culinary salt, or the marine acid united to the mineral alkali, or sometimes to magnesia. It is the property of nitre to be much more soluble in hot than cold water; but common salt is soluble very nearly as much in cold as in hot water. Whenever, therefore, the evaporation is carried by boiling to a certain point, much of the common salt will fall to the bottom, for want of water to hold it in solution, though the nitre will remain suspended by virtue of the heat. The common salt thus separated is taken out with a perforated ladle; and a small quantity of the fluid is cooled, from time to time, that its concentration may be known by the nitre which crystallizes in it. When the fluid is sufficiently evaporated,

evaporated, it is taken out and cooled, and great part of the nitre separates in crystals; while the remaining common salt continues dissolved, because equally soluble in cold as in hot water. Subsequent evaporation of the residue will separate more nitre in the same manner.

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ACID.

This nitre, which is called nitre of the first boiling, contains some common salt; from which it may be purified by solution in a small quantity of water, and subsequent evaporation: for the crystals thus obtained are much less contaminated with common salt than before; because the proportion of water is so much larger, with respect to the small quantity contained by the nitre, that very little of it will crystallize. For nice purposes, the solution and crystallization of nitre are repeated four times. The crystals of nitre are usually of the form of a six-sided flattened prism, with dihedral summits. Its taste is penetrating, but the cold produced by placing the salt to dissolve in the mouth is such as to predominate over the real taste at first. Seven parts of water dissolve one of nitre at the temperature of 60 degrees; but boiling water dissolves its own weight.

Purification of
nitre.

If nitre be exposed to a strong heat, it melts, and becomes red hot; and the volatile product is found to consist of fuming nitrous acid, a large quantity of vital air, and some phlogisticated air; the alkali remaining behind, somewhat altered by a portion of the earth of the retort which it has dissolved. Most other nitrous salts give out vital air by the same treatment. The extreme difficulty of ascertaining the weights of aerial products, and of the fixed residues, renders it an embarrassing

Decomposition
of nitre by heat.

**NITROUS
ACID.**

Deflagration of
nitre.

Detonation.

Invention of
gunpowder.

barrassing task to shew by real experiment what happens in this operation among the principles of nitre.

When a combustible body and nitre are brought into contact, either of them being previously heated red hot, the body is burned with great rapidity, no doubt by the vital air which the nitre affords by the heat; for the experiment succeeds in vacuo, and also when the bodies are surrounded by any aerial fluid incapable of maintaining combustion. This rapid combustion, effected by means of nitre, is called deflagration, when it is performed by a successive burning of the parts of the body; or detonation, when the combustion of the whole is performed in so short a time as to appear instantaneous. In this experiment it is remarkable that the combustion is maintained by vital air which is not in the elastic state, but fixed in the nitre. Whence it should follow, that either the vital air, or the combustible body, even in the fixed state, has a great capacity for heat, of which it must contain a large quantity, on the hypothesis of heat being matter. Or, if heat be a mere commotion, it will follow, that though the quantity of agitation produced by the sudden coalition of particles, in the act of converting an elastic fluid into a dense body, be such as to produce a great effect in increasing the temperature; yet the quantity is still so considerable, when vital air and combustible matter unite even in their dense state, as to cause the most intense degree of ignition.

This property of nitre has been applied to the production of a substance which has greatly affected the habits of human society, particularly in those wars which unfortunately their vices too often produce.

The

NITROUS
ACID.

Composition of
gunpowder.

The invention of gunpowder has totally changed the military system of nations; and has probably suppressed much of that malice and inveterate rancour which actuate the minds of combatants who meet hand to hand, instead of managing the instruments of indiscriminate slaughter at a distance. This destructive powder is composed of seventy-five parts by weight of nitre, sixteen of charcoal, and nine of sulphur, intimately blended together by long pounding in wooden mortars, with a small quantity of water. This proportion of the materials is the most effectual; but the circumstance on which its effect more particularly depends is, the accurate mixture of the parts. Gunpowder is granulated by making the mass into a stiff paste, and agitating it upon a wire sieve, which cuts it into small parts; and these being shaken, or rolled in a barrel, take a rounded form by their mutual friction against each other. When any grain of a heap of gunpowder is set on fire, the detonation begins, and is propagated with amazing rapidity through the interstices of the grains; a large quantity of permanently elastic fluid, consisting of one-third fixed air, and the rest phlogisticated air *, being at the same time produced. The expansion of the elastic products is the cause of the well-known effects of gunpowder. It is said that gunpowder is much weaker for being granulated. If the grains be pulverized, it is certain that the effect is much less, on account of the inflammation being propagated more slowly; but the assertion may nevertheless be true of powder which is newly made.

* Berthollet, in the Mem. Acad. Par. 1781, page 231.

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ACID.*

and has never been grained. Gunpowder which has been suffered to become damp, scarcely ever recovers its former force ; most probably because the nitre, by a partial solution, becomes separated from the mass in more distinct saline crystals than before ; and the wetting, which is necessary to the process of granulating, may weaken the powder in the same way.

Fulminating
powder.

When three parts by weight of nitre, two of mild vegetable alkali, and one of flowers of sulphur, are rubbed together in a warm mortar, they compose a powder known by the name of fulminating powder. The effects of this powder, when fused in a ladle, and then set on fire, are astonishing. The whole of the melted fluid explodes with an intolerable noise ; and the ladle is commonly disfigured, as if it had received a strong concussion downwards. A drachm of the powder makes a report as loud as a cannon ; but the noise of a few grains is sufficiently unpleasant in a room. It has very little effect, unless first melted. A mixture of liver of sulphur with twice its weight of nitre, produces the same explosion, though in less time ; whence it appears that the alkali and sulphur of the former preparation form a liver of sulphur ; and that the explosion, in all probability, arises from the sudden extrication of hepatic air from the liver of sulphur, and vital air from the nitre, which burn the instant they are formed.

Distillation of
nitrous acid.

If clay, bole, or alum, be mixed with nitre, and exposed to distillation, the nitre is decomposed, and the acid comes over ; the attraction between itself and the alkali being weakened, partly by the attraction which the vitriolic acid usually contained in those bodies has

has for its alkali, and partly by the attraction exerted between the same alkali and the siliceous earth of the clay. If strong vitriolic acid be added to nitre in a retort, the same decomposition takes place with the application of much less heat, by virtue of the superior attraction of the acid of vitriol to the alkaline base.

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Nitrous acid is usually yellow, and emits suffocating fumes of the same colour; but it may be rendered pure and colourless by a slight boiling in a retort. Aqua fortis is a weak spirit of nitre, and not remarkably pure. It usually contains some marine acid.

The assayers purify their nitrous acid by adding a small portion of the nitrous solution of silver. This metal unites with the marine acid it may contain, and falls down in the form of an insoluble compound. Care must be taken to avoid adding too much.

This acid, in combination with calcareous earth, forms a salt whose crystals deliquesce by exposure to the air. It is soluble in twice its weight of cold, or its own weight of boiling water. With ponderous earth it forms a salt of difficult solubility. With magnesia it forms an acrid bitter salt, which is very soluble in water, and deliquescent in the air. With clay it forms an austere salt of difficult solution. None of these have yet been applied to any use.

With the mineral alkali this acid forms a salt called quadrangular nitre, from the usual form of its crystals. About three times its weight of water is required to hold it in solution in a mean temperature, and it is scarcely more soluble in hot water. Its properties resemble those of common nitre; but it is

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NITROUS less fit for making gunpowder, because it attracts the humidity of the air.

—with volatile alkali.

The nitrous acid, in combination with the volatile alkali, forms nitrous ammoniac; a salt which slightly attracts the humidity of the air, and is soluble in less than its own weight of water. If this salt be exposed to heat in closed vessels, it suddenly explodes; part of the acid and alkali is destroyed; and the aerial product is phlogisticated air.

Production of nitrous acid.

If a mixture of two parts by measure of vital air, obtained without the use of nitrous acid, and one of phlogisticated air—or, which is the same thing, five parts of vital, and four of common air—be exposed to the action of the electric spark in the upper part of a syphon, in which it may be confined by mercury; and a small quantity of soap lees, or solution of pure vegetable alkali, be admitted into the cavity which contains the air; an absorption will take place, and nitrous acid will be produced, as appears by the alkali being converted into true nitre. This is a slow operation, and requires the quantity of air in the syphon to be renewed very often, to supply the absorption*. It has likewise been found that this acid is produced by exposing vital air for a long time to the exhalations of putrefying animal substances, together with calcareous earth, or any other proper base to receive and combine with it†. There can be little

Nitrous acid produced; by Mr. Cavendish:

—by M. Thouvenel.

* For the detail of the particulars of this most curious experiment, consult Mr. Cavendish's papers, in the Phil. Transf. vol. lxxv. p. 372; and vol. lxxviii. p. 255.

† This is the discovery of M. Thouvenel. See his Prize Dissertation on the Formation of Nitre.

doubt but the putrid exhalations consisted chiefly of phlogisticated air. It appears therefore that this substance bears the same relation to the nitrous acid as sulphur does to the vitriolic. As sulphur by combustion, in which vital air is an indispensable requisite, becomes converted into vitriolic acid, so phlogisticated air becomes converted into nitrous acid; though, on account of its being less combustible, the red heat cannot be produced and kept up without the co-operation of electricity: and as sulphur, when in contact with the pure air of the atmosphere, and with a base proper for combining with the vitriolic acid, is converted into that acid by a slow combustion in the pyrites; so the like exposure of phlogisticated air, in contact with calcareous earth, to vital air, produces nitrous acid, though much more slowly, because the base is less combustible.

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ACID.

Inference.

It has already been mentioned that volatile alkali is a compound of phlogisticated and inflammable air.— Hence in several metallic solutions, wherein inflammable air might else have been extricated, a production of volatile alkali has been observed to take place. This is naturally accounted for by the combination of the inflammable air with the phlogisticated air of the nitrous acid, while the other component part of the acid, namely the vital air, is employed in calcining the metal. The Rev. Isaac Milner first thought of inverting this process, and his attempts were crowned with the happiest success. He concluded, that if by any effect of the chemical affinities vital air could be made to engage with the phlogisticated air of volatile alkali, at the same time that the other principle, namely the

Nitrous acid
composed by
Mr. Milner.

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ACID.

inflammable air, should be either retained or disengaged, the result of such first combination would be the nitrous acid in some of its modifications.

For this purpose, he crammed a gun barrel full of manganese in coarse powder, which substance is known to obtain vital air by heat; and to one end of this tube be applied a retort containing the caustic volatile alkali.

Heat was then applied to the gun barrel; and, as soon as it was ignited, he placed a candle beneath the retort, which caused the volatile alkali to boil, and pass through the gun barrel in the form of alkaline air: the consequence was, that nitrous air was emitted at the other end of the tube.

He likewise repeated the experiment with success, using martial vitriol calcined to whiteness, instead of manganese*.

Nitrous acid
with combusti-
ble matter.

Nitrous air,

The nitrous acid acts with peculiar energy on combustible substances, which it burns or calcines; and during most of these processes a peculiar kind of air flies off, which is called nitrous air. It is produced by the solution of many of the metals, by most vegetable, and some animal substances. This aerial fluid is not rapidly imbibed by water, and may therefore for temporary use be received over it. It is not heavier than common air; and possesses the remarkable property of suddenly uniting with vital air, with which it forms nitrous acid. The mixture of these two kinds of air forms a red cloud, which is imbibed by

* Mr. Milner's experiments are inserted in the lxxixth vol. of the Phil. Trans. The whole paper is highly deserving the attention of chemists,

the water, and renders it acid, if the experiment be performed over that fluid ; and, from examination of this acid water, it is proved that the cloud is the nitrous acid itself. From this circumstance Dr. Priestley instituted a method of determining the purity or respirability of the air of the atmosphere, or any other permanently elastic fluid. He found, by a variety of experiments, that when nitrous air and any other air are mixed, they undergo no change, if the latter be totally unfit to support combustion or animal life ; but, if the contrary, the red cloud is formed ; and the whole bulk of the mixture is diminished by a quantity which is so much the greater, accordingly as the air in question is of a quality more suited to those purposes. This diminution he likewise proved to consist of a proportional part of the air which is tried, together with as much of the nitrous air as is required to produce the effect ; so that, if the nitrous air be duly proportioned to the effect, it will wholly disappear.

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ACID.

Dr. Priestley's
method of as-
certaining the
respirability of
air.

The trial of the purity of common air by means of nitrous air, has not however been found to exhibit such remarkable differences between the air taken up at various places as their known salubrity or unhealthiness might have given reason to expect. Two reasons may be offered to account for this. The first is, that a small difference in the purity of the air of a place may have a very considerable effect on the health of those who are obliged to breathe it for a long succession of time : the second is, that, the effects of nitrous air being the same upon elastic fluids which contain equal proportions of vital air, however greatly their other component parts may differ in their properties,

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ACID.

perties, it will only be shewn that the airs are equally salubrious, as far as depends on their proportion of vital air, though they may by no means be so with regard to their noxious parts.

Eudiometers.

There are several ingenious contrivances, called eudiometers, for the mixing of nitrous and other air, and measuring their diminution. As these however are not easily procured, and more especially as Dr. Priestley, whose experience is greater than that of any other philosopher, uses a simple tube, it does not seem necessary to describe them here. The doctor's method is as follows:

Dr. Priestley's
method of as-
certaining the
purity of air:

He first provides * a phial containing about an ounce of water, which he calls the air measure. This he fills with air, by having first filled it with water, and placed it over the opening of the funnel, in his shelf (fig. 15); and when it is filled, he slides it along the shelf, always observing that there be a little more air than is wanted. The phial being thus exactly filled with the air he is about to examine, and care being taken that it be not warmed by holding in the hand, he empties it into a jar of about an inch and a half in diameter; and then introduces to it the same measure of nitrous air, and lets them continue together about two minutes. The Doctor chooses to have an overplus of nitrous air, that he may be sure that its effect may be the utmost possible. If he finds the diminution of these two measures to be very considerable, he introduces another measure of nitrous air; but the purest vital air will not, he believes, require more than two measures of nitrous air.

* Priestley, iv. p. 30. I give the account nearly in his words.

Sometimes he leaves the common and nitrous air in the jar all night, or a whole day; but he always takes care, whenever he compares two kinds of air, that both shall remain the same length of time in the vessels, before he notes the degree of diminution.

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ACID.

When the preceding part of the process is over, he transfers the air into a glass tube, about three feet long, and one third of an inch wide, carefully graduated according to the air measure, and divided into tenth and hundredth parts; so that one of the hundredth parts will be about a sixth or an eighth of an inch. Then immersing the tube in a trough of water, so that the water in the inside of the tube shall be on a level with the water on the outside, he observes the space occupied by the aerial mixture; and expresses the result in measures and decimal parts of a measure, according to the graduation of the tube.

It is some trouble to graduate a tube in this manner; but when it is once done, the application of it is extremely easy. As it seldom happens that a glass tube is of an equal diameter throughout, the Doctor generally fills that part of the tube which contains one measure with quicksilver; and then weighing it and dividing it into ten parts, he puts them in separately, in order to mark the primary divisions. The weighing is rendered very easy by the help of a glass tube, drawn to a fine orifice, which serves to take up a small quantity at a time, as may be required in making the adjustment.

It has been already observed that common air loses about one fourth of its bulk by any process equivalent

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to

**NITROUS
ACID.**

Action of nitrous acid on animal substances.

to combustion. This also happens when it is mixed with nitrous air.

When the nitrous acid acts upon the flesh, or other parts of animal substances, the elastic fluid which is first and most plentifully disengaged is phlogisticated air. In this experiment the phlogisticated air may come from the animal substance, or the acid, or both; since both contain it. It appears however to be much more probable that the whole comes from the animal substances; for it is afforded by the application of a very weak nitrous acid, at so low a temperature as 65° or 70° ; both which circumstances do not appear to indicate a decomposition of the acid. The nitrous acid, after its action, saturates as large a quantity of alkali as before*. The quantity of phlogisticated air is in proportion to the quantity of volatile alkali which the animal substance made use of affords by distillation: and it is known that the quantity of phlogisticated air contained in any animal substance must be in this proportion. And lastly, at a greater heat, after the phlogisticated air has come over, there is a disengagement of nitrous air, which indicates a less complete decomposition of the acid than that which would have afforded phlogisticated air: and it is not consonant with other chemical facts, that the complete decomposition of the

* The quantity of alkali saturated by an acid being different according to the state of the acid, with regard to what is called phlogistication, this proof cannot be admitted as absolutely conclusive, unless the same quantity of true nitre be formed in both cases. I do not find whether this has or has not been done. See *Annales de Chimie*, i. 42.

acid

acid should happen at a lower heat than the partial decomposition which succeeds it.

Water will imbibe about one tenth of its bulk of nitrous air, which, if immediately expelled by heat, is not found to be changed in its properties. The residuum which is not imbibed is phlogisticated air. The vitriolic acid affords nitrous air, and assumes a purple colour. The marine acid imbibes it, and becomes blue. Ether, alkaline liquors, and spirit of wine, also absorb it.

The electric spark diminishes nitrous air about one half, and converts it into phlogisticated air, at the same time that acid is deposited. Iron filings and brimstone, liver of sulphur, or iron alone, being exposed to nitrous air, diminish it, and convert it into phlogisticated air. But the most singular circumstance in these processes is, that, though they are of the nature of combustion, and do in the end render air perfectly unfit for maintaining it, yet, at a certain period before this, the air is put into a state in which a candle burns in it better than in common air, though it still continues perfectly destructive of animal life. Dr. Priestley calls this dephlogisticated nitrous air.

If nitrous acid be exposed to nitrous air, the latter is absorbed in large quantities; and the colour of the acid changes first at the surface, and gradually through the whole of the liquid: the successions of colour are first yellow, then deep orange, next green, and lastly blue, according to the quantities of nitrous air absorbed. This absorption renders the acid much more volatile. Hence it appears that the various colours of nitrous acid are owing to its having absorbed nitrous air, which

NITROUS
ACID.

Various fluids
imbibe nitrous
air.

Diminution of
nitrous air by
electricity, &c.

Dephlogisticat-
ed nitrous air.

Absorption of
nitrous air by
the nitrous
acid.

**NITROUS
ACID.**

Pale nitrous
acid, becomes
yellow :

—is capable of
the elastic
form.

Inflammation
of essential oils
by nitrous
acid ;

which continually escaping, and combining with the vital air of the atmosphere, forms the yellow or reddish fumes it usually emits when in an open vessel.

The pale or dephlogisticated nitrous acid, if exposed to the action of light, gives out pure air, and itself becomes yellow and fuming. Heat also produces

the same effect. The nitrous acid itself appears to be capable of subsisting in the aërial form, though its power of combining with water, mercury, or any other fluid used for confining it, prevents experiments from being made upon it with the same facility as with other kinds of air. Water impregnated with this air or vapour becomes successively blue, green, and at last yellow, when it has received an increase of one third of its bulk. This water emits a great quantity of nitrous air, and does not seem to differ essentially from pure nitrous acid which has imbibed nitrous air.

One of the earliest known facts of spontaneous inflammation is that produced by the affusion of the nitrous acid upon oil. All the oils obtained by distillation from vegetables, and known by the name of essential oils, are proper for this experiment. An ounce of the oil intended to be set on fire must be placed in a shallow vessel, and a bottle containing an ounce of the most concentrated nitrous acid must be fastened at the end of a pole, that the operator may be sufficiently distant from the inflammation. Two thirds of the acid being poured on the oil, makes a considerable ebullition ; the oil growing black and thick, and sometimes taking fire. But if this last circumstance does not happen in five or six seconds, the remainder of the acid must be poured where the mixture appears most dry
and

and black; and then the inflammation seldom fails to take place.

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ACID.

Fat oils may also be inflamed, if equal parts of the nitrous and vitriolic acids be first poured on them, and, when the ebullition is at the greatest, a portion of nitrous acid be poured on the driest part.

—of fat oils:

Strong nitrous acid, of the specific gravity of 1.54, being added to the powder of charcoal, or lamp black*, recently made very dry, takes fire, and detonates. There is some uncertainty in this experiment; but the method which is said to ensure success, is, to put the dry powder into a very dry retort, and pour the acid upon the side of the glass, so that it may not fall upon the powder, but flow beneath it.

—of charcoal,
or lamp black.

The production of heat in these phenomena, which doubtless arises from the action exerted between the combustible body and the vital air of the acid, has not yet been explained in an adequate manner from experiments tending to shew how the capacities of the bodies are changed by the process.

On a review of the facts in the foregoing chapter, it will not be difficult to apply in a general way the same theories as were exhibited in treating of the vitriolic acid. The preparation of nitre beds consists simply in a process by which the exhalations of putrid substances may combine with vital air, and the product be received into a combination with calcareous earth, or with the alkali of decayed vegetables; and the subsequent manipulations are the mere application of water, to separate the several matters from each other according

Recapitulation
and theory.

* Proust in the Journal de Medecine, for July 1778.

**NITROUS
ACID.**

to their respective degrees of solubility. That nitrous acid contains vital air, is evident from the distillation of nitre without addition; and that in the acid it is applied to, or combined with, phlogisticated air, appears equally clear from the * experiment of Mr. Cavendish, and from the frequent appearance of this aerial substance in experiments with nitrous air. The question in this process therefore seems to be, whether the air called phlogisticated air do really contain an inflammable principle, which it gives out during combination with the vital air; or whether it simply unite to this last? Upon the former supposition, the theory of the general facts will be as follows:

Nitrous acid consists of vital air united to a certain proportion of phlogisticated air, which has been deprived of phlogiston during combination. When a combustible body is presented to this acid, it becomes corroded or burned; that is to say, it combines with some of the vital air, and parts with some of its own phlogiston. In this state the acid is no longer the same; for it has lost vital air, and part of its phlogisticated air has regained phlogiston. It therefore emits either nitrous air, which is an imperfect nitrous acid, wherein the phlogiston is too abundant, and the vital air too deficient, to exhibit acid properties; which on that account readily absorbs vital air, and is by that means precipitated again in the original acid form: or, if the decomposition be more completely made, the quantity of vital air absorbed, and of phlogiston emitted, by the combustible body, may be such as that only phlogisticated air shall be extricated, as is the case with

* Phil. Transf. quoted, page 152.

animal

animal substances. Again, the composition of nitrous air being thus established, if the electric spark be applied to produce ignition in this aerial fluid, the small portion of vital air intimately unites with as much of the phlogisticated air as is required to form nitrous acid, and leaves the residue of phlogisticated air behind: or, if any process of slow combustion be carried on in it, the whole of the vital air is absorbed, and as much phlogiston extricated as converts the residue into phlogisticated air. It is evident that the absorption of nitrous air must equally alter the proportions of the component parts of the nitrous acid, and produce similar effects.

The singular properties of the air called dephlogisticated nitrous air have not been satisfactorily explained upon any theory.

It is obvious that the explanation of these events may be made at least with equal facility according to the other theory. Phlogisticated air and vital air are applied to each other under certain circumstances, and nitrous acid is produced. Hence it is concluded that these aerial substances have united together, and are the component parts of nitrous acid. When an inflammable substance is burned, or a metal calcined, by the action of this acid, one of its component parts, namely, vital air, unites with the body; and the surplus of the other principle, namely, phlogisticated air, flies off either alone, or in combination with a sufficient portion of vital air to form nitrous air. The addition of vital air to this last aerial product completely forms nitrous acid; the subtraction of the vital air it possesses must change it into phlogisticated air.

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ACID.

Page 169.

Ibid.

Ibid.

Theory :

—of the anti-
phlogisticians.

The

NITROUS
ACID.

Action of light.

Theory.

Keir's com-
pound acid.
See chap. ii.
book ii.

The phenomenon of nitrous acid becoming yellow and fuming by the action of light or heat, will shew that it receives phlogiston, according to the ancient hypothesis. As it seems however to be a bold supposition, that either light or heat, considered as matter, can transfer the inflammable principle through glass vessels, the fact has been more ingeniously explained by recourse to the decomposition of water. It is asserted that the nitrous acid attracts the inflammable air, or phlogiston, of the water, and sets its vital air at liberty. According to the antiphlogistic theory, it is simply said that heat or light expels part of the vital air from the nitrous acid, as the event shews; and that the residue, having an over-proportion of phlogisticated air, is of course coloured and fuming.

The reader may easily apply these theories to the combustion of oils or charcoal by the nitrous acid, as far as the facts can be clearly stated, or are known: for these are doubtless of the same nature as other combustions.

It is a late discovery of Mr. Keir*, that a mixture of the concentrated vitriolic and nitrous acids forms a solvent peculiarly calculated to dissolve silver in a large proportion; though it has scarcely any efficacy in suspending any other metallic substance. He forms it by dissolving nitre in concentrated vitriolic acid. Tin, mercury, and nickel, are acted upon, and chiefly calcined, by this compound acid; the latter being dissolved in a small quantity: but it has little or no action upon the other metals. Dilution with water renders it less capable of dissolving silver, but more active with regard to the other metals.

* Phil. Transf. vol. lxxx. p. 373.

If this acid be digested upon sulphur, it undergoes the change called phlogistication, and emits nitrous fumes; the nitrous acid probably losing its acidity in proportion as the sulphur becomes acidified. Its affinities, or solvent powers, are considerably changed by this process. The same phlogisticated acid is afforded, if the nitrous vapour or air be added to vitriolic acid, instead of common nitre; or if nitre with basis of volatile alkali be used.

NITROUS
ACID.

C H A P. III.

OF THE MARINE ACID AND ITS COMBINATIONS, INCLUDING AQUA REGIA.

COMMON
SALT.

Salt mines and
springs.

Sea water.

Extraction of
common salt
from waters.

THE marine acid is obtained from common culinary salt, in which it is united to the mineral alkali. Common salt is found in large masses, or in rocks, under the earth, in England and elsewhere. There are also many salt springs in various parts of the world; and the waters of the ocean every where abound with it, though in different proportions. The water of the Baltic sea * is said to contain one sixty-fourth of its weight of salt; that of the sea between England and Flanders contains one thirty-second part; that on the coasts of Spain one sixteenth part; and between the tropics it is said, perhaps erroneously, to contain from one eleventh to one eighth part.

The whole art of extracting salt from waters which contain it, consists in evaporating the water in the cheapest and most convenient manner. In England, a brine composed of sea water, with the addition of rock salt, is evaporated in large shallow iron boilers; and the crystals of salt are taken out in baskets. In Russia, and probably in other northern countries, the sea water is exposed to freeze; and the ice, which is almost entirely fresh, being taken out, the remaining brine is much stronger, and is evaporated by boiling.

* Romé de l'Isle's Crystallographie, vol. i. p. 375, quoted by Magellan in his improved edition of Cronstedt, p. 360.

In the southern parts of Europe the salt-makers take advantage of spontaneous evaporation. A flat piece of ground near the sea is chosen, and banked round, to prevent its being overflowed at high water. The space within the banks is divided by low walls into several compartments, which successively communicate with each other. At flood tide, the first of these is filled with sea water; which, by remaining a certain time, deposits its impurities, and loses part of its aqueous fluid. The residue is then suffered to run into the next compartment; and the former is again filled as before. From the second compartment, after a due time, the water is transferred into a third, which is lined with clay, well rammed, and levelled. At this period the evaporation is usually brought to that degree, that a crust of salt is formed on the surface of the water, which the workmen break, and it immediately falls to the bottom. They continue to do this until the quantity is sufficient to be raked out, and dried in heaps. This is called bay salt.

COMMON
SALT.

Various me-
thods

—of obtaining
salt:

—from the wa-
ters

In some parts of France, and also on the coasts of China, they wash the dried sands of the sea with a small proportion of water, and evaporate this brine in leaden boilers.

At several places in Germany, and at Montmarot in France, the waters of salt springs are pumped up to a large reservoir at the top of a building or shed; from which it drops or trickles through small apertures upon boards covered with brush wood. The large surface of the water thus exposed to the air, causes a very considerable evaporation; and the brine is afterwards con-

—and salt
springs.

N

vayed

COMMON
SALT.

Salts contained
in the sea.

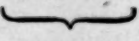
veyed to the boilers for the perfect separation of the salt.

The water of the sea contains, besides the common salt, a considerable proportion of magnesian marine salt, and some gypsum, or lime combined with vitriolic acid. The magnesian salt is the chief ingredient of the remaining liquid which is left after the extraction of the common salt, and is called the mother water. Sea water, if taken up near the surface, contains also the putrid remains of animal substances, which render it nauseous, and in long continued calms cause the sea to stink.

Crystallization
of common
salt.

The crystals of common salt are right-angled six-sided solids, and are usually said to be cubes. These form at the surface, where the evaporation is the greatest; and they float by virtue of the repulsive power of their dry upper surfaces, which displaces a quantity of the surrounding water: a circumstance common to all such small bodies as are not easily wetted. When the crystal becomes too large to be suspended in this way, it sinks. If two floating crystals come so near each other as that the hollow spaces may communicate, they fall together into one cavity at the surface, without sinking; and the successive apposition of other crystals often produces a curious hollow pyramid, which is square, because the figure of the crystals themselves occasions them to apply to each other only in the position required to produce such a solid.

Common salt does not alter in the air; but when exposed to heat, it cracks and flies in pieces, by the escape

escape of its water of crystallization. A greater heat ignites and melts it; and a still greater causes it to rise totally in white fumes. The action of sea salt upon earths is not considerable. It assists the fusion of siliceous earth; and is thrown into the furnace wherein the pottery called stone-ware is baked, where it rises in fumes, and glazes their surface; probably by the combination of its alkali with the siliceous earth contained in the clay. The decomposition of sea salt by litharge has already been mentioned in treating of the mineral alkali. MARINE ACID. 

Page 122.

The marine acid may be obtained from common salt by processes similar to those described for procuring the nitrous acid in the preceding chapter. The most effectual and elegant way consists in applying one part by weight of strong vitriolic acid to three of decrepitated sea salt, in a retort whose upper part is furnished with a tube or neck, through which the acid is to be poured upon the salt. The aperture of this tube must be immediately closed with a ground stopper after the pouring. The vitriolic acid immediately combines with the alkali, and expels the marine acid in the form of a peculiar air; which is rapidly absorbed by water, but may be confined by mercury. As this combination and disengagement take place without the application of heat, and the aerial fluid escapes very readily, it is necessary to arrange and lute the vessels together before the vitriolic acid is added, and not to make any fire in the furnace until the disengagement begins to slacken; at which time it must be very gradually raised. Before the modern improvements in chemistry were made, a great part of

Distillation of marine acid from common salt.

Marine acid air:

MARINE
ACID.
Distillation

the acid escaped, for want of water to combine with; but by the use of the apparatus, fig. 21 or 22 (or a combination of vessels equivalent to both of them), the acid air is made to pass through water, in which it is condensed, and forms marine acid of double the weight of the water, though the bulk of this fluid is increased one half only. The acid condensed in the first receiver, which contains no water, is of a yellow colour, arising from the impurities of the salt.

Marine acid
air :

Heat expels the marine acid air from marine acid, and leaves the water behind. The fumes of spirit of salt consist of this air in the act of uniting with the watery vapours of the atmosphere, which render it visible. This air has nearly the same affinities as the acid itself in the fluid form. The electric explosion diminishes it a little; but the remainder is almost totally soluble in water as before.

—its corrosive
nature.

It is an object of considerable importance to the practical chemist, to be aware of the corrosive nature of this acid air. If the processes in which it is set at liberty be carried on in a room where balances and other metallic instruments are kept, though the quantities may not be perceptible by the smell or otherwise, yet the instruments will in the course of a few days be covered with rust. It is indeed by no means prudent to keep, or make use of, any delicate metallic instruments in the same apartment which is appropriated to chemical processes.

Salt of Sylvius. The marine acid, in combination with the vegetable alkali, forms a salt called salt of Sylvius, or, improperly, regenerated sea salt. It is of a bitter taste, slightly deliquescent, and soluble in about three times

its

its weight of water. This is sometimes used in medicine.

MARINE
ACID.

With the volatile alkali it forms common sal ammoniac, which is a consistent salt, of a sharp briny taste; and so remarkably deficient in the usual brittleness of this class of bodies, that it is not easily pulverized. It is soluble in between three and four times its weight of water, in a common temperature. By heat it sublimes entire in closed vessels.

Sal ammoniac.

The saline combination of lime with marine acid is sometimes called marine selenite, and sometimes fixed ammoniac; because it forms the fixed residue after sal ammoniac has been exposed to distillation with lime. This salt may be obtained in the form of crystals, but it deliquesces with air. It is soluble in less than twice its weight of cold water. The combination of lime and marine acid which remains after distilling sal ammoniac, has usually an over-proportion of lime. If it be urged by a violent heat, it fuses; and when cold, it has the property of emitting a phosphoric light upon being struck with any hard body. Hence it is called Homberg's phosphorus, from the name of the first observer.

Marine selenite.

Homberg's
phosphorus.

The argillaceous marine salt has a gelatinous consistence when dissolved in a small quantity of water. Its taste is styptic, and it affords crystals by spontaneous evaporation.

Argillaceous
marine salt.

The combination of ponderous earth with marine acid forms a crystallizable salt of difficult solution. Its solution is of admirable use for detecting the presence of the vitriolic acid in any fluid; because this air combines with the earth, and forms an insoluble

Ponderous marine salt.

MARINE
ACID.

precipitate of ponderous spar. It is more especially useful for purifying the marine acid itself from the vitriolic acid, which it often contains. The exact quantity of solution necessary to be added for this purpose to any vessel of marine acid, may be known by previous trials with small portions of the acid.

Magnesian ma-
rine salt.

Magnesian marine salt exists in all salt waters. It is soluble in less than its own weight of water; and cannot be obtained in the crystalline form but by first evaporating its solution, and then suddenly exposing it to a great degree of cold. It is the cause of the bitterness of sea water: and, like most of the other salts last described, it is applied to no useful purpose.

Action of ma-
rine acid upon
metals.

The marine acid has scarcely any action upon combustible substances in general. It acts directly upon tin, lead, copper, iron, zinc, bismuth, antimony, manganese, arsenic; but does not affect gold, silver, platina, mercury, wolfram, or cobalt.

Dephlogisti-
cated or aerated
marine acid.

If the marine acid be distilled from about one fourth of its weight of the black calx of manganese, a suffocating elastic fluid arises, which corrodes mercury, and is absorbed by water. The impregnation of water with this fluid (which was named the dephlogisticated marine acid by its discoverer SCHEELÉ) may be conveniently performed by means of the apparatus, fig. 21 *. If the concentrated marine acid be used, the disengagement takes place without heat; but if it be weaker, the application of a gentle heat is necessary. The common marine acid which may rise is condensed in the first bottle; and the dephlogisticated acid unites to

* Berthollet, in the Mem. Acad. Par. for 1785; and in Rozier's Journal for Sept. 1788.

the water in the second; the water, as it becomes saturated, assumes a greenish yellow colour. When the saturation is complete, the dephlogisticated acid takes a concrete form, and descends to the bottom in yellowish flocks, provided the temperature of the water be only a few degrees above freezing. An increase of temperature, such as may be produced by applying the hand to the vessel, causes this concrete matter to assume the aerial form, and escape in bubbles to the surface. The taste of the solution is austere, but does not resemble that of acids. It combines with fixed alkalis without causing them to give out their fixed air, if they be in a mild state. Heated with lime, or fixed alkali, it emits vital air, and then forms the same saline combinations as the common marine acid would have done. It dissolves all metals directly, without affording inflammable air, as the marine acid does with some of them; and its saline combinations are, for the most part, the same as the common acid produces when made to combine with those bodies. It destroys vegetable colours, rendering them white without first causing them to become red; it bleaches wax; and in general produces immediately, in a variety of substances, the same changes as are effected by long exposure to air. This property has already been applied with success in manufactories.

MARINE
ACID.

Dephlogisticated or aerated marine acid.

Annales de
Chimie, ii.
151—190.

When the aëriform dephlogisticated marine acid is received in a solution of pure vegetable alkali, and the liquor evaporated, two kinds of salt are obtained. The one is the common salt of Sylvius, which separates from the fluid as the evaporation goes on; and the other is a salt which, being more soluble in hot

Salt into which dephlogisticated marine acid enters,

MARINE
ACID.

Detonating marine salt with base of vegetable alkali :

than in cold water, affords crystals by cooling. These are of a long rhomboidal figure, and a silvery brilliancy ; have an insipid cooling taste, resembling nitre ; do not deliquesce in the air ; and detonate with charcoal, or with iron, more strongly than nitre itself does. By heat alone they give out vital air ; and the residue of their detonation with charcoal is the salt of Sylvius. Hence it is obvious, that a portion of the alkali has imbibed some of the dephlogisticated marine acid, together with the overplus of vital air contained in a great part of the rest of the acid ; and that this alkali forms the present salt ; while the acid which was deprived of the overplus, and by that means reduced to the common state, forms the salt of Sylvius, which is in much the greatest proportion in the solution.

—with mineral alkali :

If the mineral alkali be used, a salt nearly of the same nature is formed ; but too deliquescent to afford crystals.

—volatile alkali.

Volatile alkali is decomposed by the dephlogisticated marine acid ; the vital air combining with its inflammable part, and the phlogisticated air flying off.

Action of light.

When the solution of dephlogisticated marine acid is exposed to the action of light, it emits vital air, and becomes converted into common marine acid.

Theory.

When we reason by analogy from the vitriolic and nitrous to the marine acids, we must conclude that this last consists of a base of a combustible nature united to vital air. And as the greater combustibility of sulphur, the base of the vitriolic acid, when compared with phlogisticated air, or the base of nitrous acid, appears to be the cause why the action of the latter is more generally effectual upon combustible bodies,

bodies, to which it can with more facility transfer its vital air, and probably receive phlogiston from them at the same time; so the base of marine acid, being apparently less combustible than even that of the nitrous, may, in its ordinary state of acidity, hold too small a quantity of vital air, or too large a proportion of phlogiston, to act with energy on other combustible bodies. But whenever it is combined with a surplus of vital air from the calx of manganese (which certainly contains it, because it affords it by simple heat), it must act with great effect on bodies which are disposed to combine with that principle, for the same reason as the nitrous acid does; namely, because it is easily decomposed. And this reason will in fact be the same, whether the action of acids be considered according to the modern theory, as consisting chiefly in the combination of vital air with the combustible body; or whether this last be supposed in the old theory to afford phlogiston to the base, or other component part, of the acid.

MARINE
ACID.

Theory.

Action on
combustible
bodies.

It must be confessed however, that the general circumstances attending the change which the marine acid suffers by the accession of vital air, are not strictly consonant throughout with what happens to the other acids. The phlogisticated vitriolic and nitrous acids are rendered more acid by the addition of vital air, which is generally admitted to be the chief principle of acidity. The marine acid, on the contrary, has its activity increased, by such an addition or change, only with respect to combustible bodies; but is less active on the alkalis and earths, inasmuch that some writers have thought it might be denied to be an acid.

Acidity of marine acid does not vary after the law of other acids.

AQUA
REGIA.

Theory.

acid. From this instance acidity appears to have its limits, so as to consist of a precise term of dephlogistication, or of saturation with vital air; and to be impaired or destroyed by an excess either way. A full and adequate explanation of the changes of the marine acid cannot but afford much advantage to the general theory of acids, which occupy so large a space among the objects of chemical inquiry.

Composition of
aqua regia :

When one or two parts of pale concentrated nitrous acid are mixed with four parts of fuming marine acid, an effervescence soon takes place*, and dephlogisticated marine acid flies off in the aerial form, at the same time that the mixture becomes of a deep red colour. The mixed acid is called aqua regia; and has been long remarkable for its property of dissolving gold, which is not sensibly acted upon by either of the acids that compose it.

—otherwise.

Aqua regia may be made by adding to nitrous acid any salt which contains the marine acid: for the affinity of the nitrous acid to the base being in most cases stronger than that of the marine, this last is set at liberty; and consequently the mixture, if the salt be not excessive in quantity, will contain the acids in a disengaged state. An aqua regia will therefore be produced, which is not essentially impaired with respect to common uses by the portion of salt it may hold in solution. It is usual to make aqua regia by dissolving sal ammoniac in about four times its weight of strong nitrous acid; but the results

* Berthollet, in Acad. Par. 1785.

of experiments or operations must vary considerably according to the proportion and the ingredients made use of.

AQUA
REGIA.

The nature of this mixed acid has not yet been clearly ascertained. After the discovery of the dephlogisticated marine acid, it was concluded, that the nitrous acid performed the same office as the manganese does; that is, in fact, that it either deprives the marine acid of phlogiston, or affords vital air to combine with it, or both. Several difficulties however oppose this supposition. If the marine acid be enabled to calcine and dissolve gold because it has been dephlogisticated or aerated by the nitrous acid, it should follow much more strongly that the nitrous acid itself should dissolve that metal, which is contrary to the fact. And, again, it has not been shewn how this dephlogisticated acid, which is so volatile, and so sparingly soluble in water, is retained in the solution: not to mention that no component part of the nitrous acid is found to escape during the effervescence, except the vital air which enters into the composition of the gas that flies off. When the two acids are in due proportion, therefore, aqua regia must consist of marine acid, and nitrous acid which has an under-proportion of vital air, or is in the most fuming state; or, in other words, it contains the two bases of the acids, together with vital air, less in quantity than they possessed in their separated state. But, whether these principles combine and form a compound acid, or in what other order they may be arranged, has not yet been experimentally determined; though the writings of chemists abound with conjectural inferences respecting them.

The effects and
theory of aqua
regia.

The

AQUA
REGIA.

Combinations.

The combinations of earths and alkalis, and even of metals, with aqua regia, have not been well examined.

It is not known whether two different kinds of salts are formed apart from each other, or whether a triple combination takes place consisting of two acids united to one base. It appears however that in some cases the result is one entire compound, and in others two separate ones.

C H A P. IV.

OF FIXED AIR, FIXABLE AIR, OR AERIAL ACID.

THE acid which is commonly known by the name **FIXED AIR.** of fixed air, abounds in great quantities in nature, and appears to be produced in a variety of circumstances. It composes about one third of the weight of limestone, marble, calcareous spar, and other natural specimens of calcareous earth, from Substances which contain fixed air. which it may be extricated either by the simple application of heat, or by the superior affinity of some other acid; most acids having a stronger action on bodies than this. This last process has been before described. Page 52—554 It does not require heat, because fixed air is strongly disposed to assume the elastic state. Water, under the common pressure of the atmosphere, and at a low temperature, absorbs somewhat more than Impregnation of water. its bulk of fixed air, and then constitutes a weak acid. If the pressure be greater, the absorption is augmented. Heated water absorbs less; and if water impregnated with this acid be exposed on a brisk fire, the rapid escape of the aerial bubbles affords the appearance of the water being at the point of boiling, when the heat is not greater than the hand can bear. Congelation separates it readily and completely from water; but no degree of cold or pressure has yet exhibited this acid in a dense or concentrated state of fluidity.

Fixed air is nearly twice as heavy as common air; and for that reason occupies the lower parts of such mines

FIXED AIR. mines or caverns as contain materials which afford it by decomposition. The miners call it choke damp.

Groto del Cano. The Groto del Cano, in the kingdom of Naples, has been famous for ages on account of the effects of a stratum of fixed air which covers its bottom. It is a cave or hole in the side of a mountain near the lake Agnano, measuring not more than eighteen feet from its entrance to the inner extremity; where if a dog, or other animal that holds down its head, be thrust, it is immediately killed by inhaling this noxious fluid.

Fixed air emitted from fermenting bodies.

Experiments made in an atmosphere of fixed air.

Fixed air is emitted in large quantities by bodies in the state of the vinous fermentation; and on account of its great weight it does not fly off, but remains in the upper space of the vessel, not occupied by the fermenting body. A variety of striking experiments may be made in this stratum of elastic fluid. Lighted paper or a candle dipped into it, is immediately extinguished; and the smoke remaining in the fixed air renders its surface visible, which may be thrown into waves by agitation, like water. If a dish of water be immersed in this air, and briskly agitated, it soon becomes impregnated, and obtains the lively taste of Pyrmont water. In consequence of the weight of the fixed air, it may be dipped out in a pitcher, or bottle; which, if well corked, may be used to convey it to great distances. The effects produced by pouring this invisible fluid from one vessel to another, have a very singular appearance: if a candle, or a small animal, be placed in a deep vessel, the former becomes extinct, and the latter expires, in a few seconds after the fixed air is poured upon them, though the eye is incapable of distinguishing any thing that is poured.

When

When vegetable substances are exposed to a strong heat in vessels partly closed, the volatile principles fly off; but combustion does not take place for want of air. The fixed residue is the inflammable substance called charcoal. For general purposes, wood is converted into charcoal by building it up in a pyramidal form, and covering the pile with clay or earth, leaving a few air-holes, which are closed when the mass is perfectly lighted; and by that means the combustion is carried on in an imperfect manner. Common charcoal, when exposed to heat in closed vessels, gives out a small quantity of inflammable air, which seems extraneous to it; and if it be burned, it leaves a small portion of earth, fixed alkali, and other salts. The greater part of charcoal therefore consists of an inflammable substance; and it is found that, if this be burned in a closed vessel over mercury, with vital air, the product is fixed air, and nothing else; as is proved by the residue after the fixed air has been absorbed by caustic fixed alkali: for there is either no aerial residue, or the residue consists of vital air as pure as at first*.

FIXED AIR.

Conversion of vegetable matter into charcoal.

Production of fixed air from charcoal.

Hence it follows, that fixed air consists of the inflammable matter of charcoal united to vital air. The antiphlogistian philosophers consider this matter as a peculiar combustible and acidifiable base, and thence infer the presence of charcoal in all cases where fixed air is extricated or produced: but, on the other hand, several of the phlogisticians think themselves justifiable in concluding that fixed air is produced by the union

Composition of fixed air.

Opinions.

* Lavoisier in Mem. Acad. Par. for 1781, p. 449.

FIXED AIR. of inflammable air with vital air, when either of them is in the nascent state, or state of extrication.

The electric spark passed through fixed air.

Phlogistic explanation.

Antiphlogistic explanation.

When the electric spark * is passed through fixed air confined by mercury, the volume of air is augmented about one twenty-fourth part; and of this three fifths are absorbed by a solution of caustic alkali, and the remainder is inflammable. An eminent philosopher of the phlogistic opinion supposes this effect to arise from the decomposition of the fixed air, whose vital air, combining more intimately with part of the inflammable air, forms water, the residue of this last air being disengaged. But the chemist who made the experiment accounts for it as follows, without supposing the fixed air to be decomposed:—The air of the atmosphere, and other elastic fluids, are proved by experiment to be capable of retaining mercury in solution; so likewise in all probability does the fixed air: and they all retain much water. Whenever therefore the electric spark, by passing through this mixture of fixed air, mercury, and water, ignites a minute portion of it, the vital air of the water unites with and calcines the mercury; while the inflammable air of the water is set at liberty; and the fixed air, like other acids, unites to the mercurial calx, and falls down with it. He supposes, from analogy, that the water in the fixed air increases its volume by rarefying it; and that the subtraction of the water occasions a contraction, while

* This experiment, first performed by Priestley, i. 243, has since been repeated by Van Marum and others. The experiment of M. Monge, quoted by Kirwan in his Essay on Phlogiston, p. 193, second edition, is that spoken of in the text: and the opinions are those of Mess. Kirwan and Monge.

the disengagement of the inflammable air produces a FIXED AIR.
 somewhat greater augmentation of bulk. In this way
 (supposing the water and mercury to be present in suf-
 ficient quantity) the whole of the fixed air may enter
 into a solid combination, and nothing remain but in-
 flammable air. Additional experiments must however
 be made, before either opinion can be established.

Fixed air does not appear to be strongly disposed to
 unite with argillaceous earth. Most clays however
 afford a small quantity of this fluid by heat; and the
 snowy white substance resembling chalk, and known
 by the name of *lac lunæ*, is found to consist of clay
 saturated with fixed air. A saline substance, consist-
 ing of two six-sided pyramids joined at one common
 base, weighing five or six grains, and of a taste some-
 what resembling alum, was produced by leaving an
 ounce phial of water, impregnated with fixed air and
 a redundancy of earth of alum, exposed to spontaneous
 evaporation for some months.

Combinations
 of fixed air;
 with clay:

Calcareous earth and fixed air have a strong attrac-
 tion for each other. Most of the specimens of cal-
 careous earth abound with this acid; and the imme-
 diate precipitation of lime from lime-water is the test
 of the presence of this acid.

—with calca-
 reous earth:

Ponderous earth combines very strongly with fixed
 air. This compound has been found in England; and,
 like the foregoing, has already been treated of in the
 chapter on earths.

—with ponde-
 rous earth:

Magnesia unites readily to a large proportion of
 fixed air.

—with mag-
 nesia.

The usual method of procuring magnesia is, by pre-
 cipitation from a solution of Epsom salt, by adding

Page 106.

FIXED AIR. an alkali which combines with the acid. When a mild fixed alkali is used, it is necessary that the saline solutions should be boiling hot, and the ebullition continued for a short time, in order to dissipate a portion of fixed air, which would hold part of the magnesia in solution. From this cause it is, that perfectly mild vegetable alkali affords no precipitate when added to a solution * of Epsom salt at the temperature of 60°. The mineral alkali, which contains less fixed air than the crystallized vegetable alkali, likewise affords but a small quantity of precipitate, unless heat be applied. Mild volatile alkali also possesses the property of affording no precipitate when added to a solution of Epsom salt in the cold: with a greater heat magnesia is separated; and at a boiling heat it is again taken up, most probably forming a triple salt composed of vitriolic acid united to volatile alkali and magnesia. The saline combination of magnesia and fixed air is separated in crystals from all these cold solutions by standing uncovered; during which time the fixed air, which held the magnesia in solution, is no doubt gradually dissipated. The crystals afforded when vegetable alkali is used, are contaminated with vitriolated tartar, which separates at the same time; those obtained by mineral alkali are finer and purer: but the most beautiful and purest are obtained by leaving the solution to which volatile alkali has been added, exposed for some days in an oblong vessel.

* One part Epsom salt, dissolved in six parts water, was mixed with one part crystallized vegetable alkali, dissolved in five parts water. Consult Fourcroy in the *Annales de Chimie*, ii. 282, from whom the whole of this article respecting aerated magnesia is taken.

This crystallized aerated magnesia has usually the **FIXED AIR** form of six-sided prisms. It is almost tasteless; effloresces in the air; becomes pulverulent by heat, by the loss of its fixed air and water; is soluble in about forty times its weight of water at the temperature of 55°. Half its weight consists of fixed air, one fourth water, and one fourth magnesia; whereas the common aerated magnesia obtained by rapid precipitation contains forty parts magnesia, forty-eight fixed air, and twelve water.

Combinations
of fixed air:

All the earthy combinations of fixed air are nearly —with earths: insoluble in water; they are all more soluble with an excess of that acid than in mere water; and they all give out their fixed air by heat, except the native specimen of aerated ponderous earth. The last contains no water; and water seems to be essentially necessary to enable bodies to assume the aerial form.

Fixed air has no action upon siliceous earth.

The three alkalis form concrete crystallizable salts —and with alkalis: when united with fixed air, which being in fact neutral salts, are much less active than the caustic or pure alkalis themselves. These salts still continue to be called the mild alkalis; because the fixed air, though it forms a large proportion of their weight, is displaced by most other acids, and therefore does not obviously seem to impair their alkaline properties: besides which, as this volatile acid flies off in the elastic form, and is lost in common experiments (exhibiting no other indication of its presence than the violent ebullition which accompanies its escape), it was formerly overlooked, and even at the present time is not always sufficiently attended to.

FIXED AIR.

Alkaline air and fixed air unite, and form the concrete volatile alkali.

Combination
of fixed air
with combusti-
ble matter.

The combinations of fixed air with inflammable substances have not been accurately examined. Metallic calces usually contain more or less of this acid. Plumbago, or black lead, is the most remarkable compound into which it enters. This affords much fixed air: but chemists are not agreed with respect to its combustible part; some considering it as the mere principle of inflammability, and others asserting it to be iron.

Advantages
derived from a
knowledge of
this acid.

When we take a retrospective view of the numerous difficulties in chemical science respecting the mild and caustic state of lime and alkalis, and their effervescence with acids in the one but not the other state; the interrupted effects of affinities; the pernicious effects of caverns, or of places where charcoal is burned, or processes of fermentation are carried on; the nature of medicinal springs, and the component parts of a large proportion of mineral as well as organized bodies, which embarrassed the world before the discovery of this acid; we have just reason to affirm that the name of Dr. Black of Edinburgh would have been immortal, if this had been the only one of the many discoveries which he has added to the mass of human knowledge.

CHAP. V.

OF THE ACID OF BORAX.

BORAX is a salt which comes to us from the East

BORAX.

Indies, and whose origin has till lately been very dubious. At present however it is very well ascertained * that it is dug up in a crystallized state

from the bottom of certain salt lakes in a mountainous, barren, volcanic district, about five-and-twenty

Natural production of tincal or crude borax.

days journey to the eastward of Lassa, the capital of

the kingdom of Thibet. Tincal, or crude borax,

in the state we receive it, is of a dull white or

greenish colour, in irregular crystals, covered with

a rancid oily substance, said to be added to prevent

its deliquescing, and intermixed with earthy impuri-

ties. It is not well known in what proportions the

component parts exist in the borax when dug out of

the earth; because it is said to be purified by subse-

quent solution in water and crystallization soon after

it comes from the mountains: and the borax of

commerce is chiefly refined in Holland by a process

Purification of borax.

which is kept a secret; though there is little doubt

but it consists of solution, filtration, crystallization,

and calcination, to free it from the impurities and

grease; and afterwards a second solution and crystal-

lization, probably with an addition of mineral alkali,

or salt of soda. M. Chaptal, after trying various

* Phil. Trans. vol. lxxvii. No. 21. 29.

**BORAX AND
ITS ACID.**

processes in the large way, found the method of calcination to be attended with loss; and approves of strong and continued boiling with water, and crystallization, followed by a second solution, ebullition, and crystallization, as the simplest method of purifying this salt *.

Analysis of borax.

If borax be dissolved to saturation in boiling water, and the vitriolic acid be added in such a quantity as to be perceptibly in excess, a salt will be disengaged, during the cooling, in white scales, which will swim at the surface of the fluid. These being taken out, the remaining solution affords Glauber's salt by evaporation. This last salt, consisting of the vitriolic acid united to mineral alkali, affords a proof that the alkali was one of the component parts of the borax: and when, by adding the disengaged scaly salt to mineral alkali in a due proportion, borax is reproduced, we have a complete proof that the scaly salt is the other component part. It was originally denominated sedative salt, but is now known by the name of acid of borax.

The acid of borax may be obtained also by sublimation; the alkaline base being separated by the previous addition of some stronger acid.

Habitudes of borax:

Borax contains a larger proportion of alkali than is necessary to saturate the acid. Some of the alkali is said to be added in the purification of the tincal. This purified salt requires about eighteen times its weight of water to dissolve it, at the temperature of 60°. When heated, it swells up, loses its water of crystallization, and runs into a kind of glass, which

* Elements of Chemistry, Eng. translation, i. 277.

may be dissolved in water, and crystallized, as before. BORAX AND
ITS ACID.

The acid of borax requires about fifty times its —and its acid. weight of water to dissolve it. In a moderate heat it melts with less intumescence than borax itself; and the glassy substance, thus formed, is again soluble in water, having only lost its water of crystallization.

Borax is used as a flux in foldering, and its acid is a very useful flux for experiments with the blow-pipe.

The acid of borax has been found uncombined in the waters of certain lakes in Tuscany. There have been several accounts of the artificial production of borax said to be practised in China, and verified by experiments made in France; but they all want farther confirmation. Native acid of
borax.

It has lately been discovered that a crystallized stone, found in a cleft near the top of a stratified mountain composed of plaster stone or gypsum, contains a large proportion of the acid of borax*. This mountain, which bears the name of Kalkberg, is situated near Luneberg in the duchy of Brunswick; and the stone which has been called cubic quartz, but is known to the inhabitants of the vicinity by the name of wurfelstein, is usually of a white colour, often grey, and sometimes of a violet tinge. Its figure, when perfect, appears at first sight to be cubic; but, when attentively inspected, is found to be composed of twenty-six faces. Most specimens are opaque; some are semi-transparent, Hard crystal-
lized stone
containing acid
of borax.

* See the *Annales de Chimie*, ii. 101 and 137, for examinations of this mineral, by M. Westrumb and by M. Hoyer. The former is referred to in the text.

BORAX AND
ITS ACID.

Analysis of the
native combination of the
acid of borax
with lime and
magnesia.

and a few are perfectly transparent. The greater number of these crystals have the appearance of having been corroded. It is evidently of a laminated texture; though its fracture seems to exhibit a radiated appearance. Its specific gravity is about 2.566, and its hardness is such that it scratches glass, and gives fire plentifully with the steel.

This stone loses its transparency by ignition, and becomes pulverable if quenched in water; though the hardness of its particles causes it to abrade the hardest mortars which can be used. An extreme degree of heat causes it to run into a yellow glass. Water does not dissolve it, either cold or by ebullition. Alkalis act upon it in the dry way, but not readily; and in this operation a considerable loss of weight is experienced. Acids, by long boiling upon the pulverized stone, dissolve it for the most part. Five days boiling of marine acid upon one hundred grains of the stone dissolved it at last.

The solution in marine acid first exhibited foliated crystals at its surface, which fell to the bottom; and as the evaporation proceeded, the whole mass fixed into a yellowish white substance. This was soluble in water, and let fall a small portion of siliceous earth. The solution, being examined by the methods of analysis hereafter to be described, afforded a small quantity of iron, with some lime; and, by the addition of vitriolic acid and sublimation, the acid of borax was obtained. An additional quantity of this substance was afforded by washing the residue with the strongest ardent spirit, and evaporating the solution till crystals were afforded. The component parts of the stone were thus found to

be—Acid of borax deprived of its water of crystallization by a red heat, 68 parts; magnesia, $13\frac{1}{2}$; lime, 11; clay, 1; calx of iron, 1; filix, 2; loss in the operation, $3\frac{1}{2}$. By adding the mineral alkali to the acid thus obtained, a true borax was formed.

BORAX AND
ITS ACID.

The acid of borax combines in the humid way with the calcareous, ponderous, and magnesian earths, and also with the alkalis, forming compounds hitherto but little examined. It does not directly dissolve the metals in the humid way; but notwithstanding its weak affinity, compared with other acids, it is probable that the combinations might be effected by double affinity. It dissolves siliceous earth in the dry way. Spirit of wine dissolves it, and burns with a green flame when set on fire.

Combinations
of the acid of
borax with
earths and al-
kalis.

No attempts have been made to decompose this acid, or to exhibit it in the aerial form. Some German chemists have lately obtained a metallic substance by treating borax with charcoal in a strong fire, in the way of reduction. But it is at present generally admitted that this metal was iron, from the crucible*.

Supposed re-
duction of bo-
rax.

* Ruprecht in the Journal de Physique for 1790.

C H A P. VI.

OF THE ACID OF SPAR.

ACID OF
SPAR.

Fluor or Derbyshire spar.

THE fusible spar, or fluor, which is commonly known in England by the name of Derbyshire spar, contains a peculiar acid united to calcareous earth. The texture of this compound is either sparry, or irregularly shattered or cracked. It is either transparent or opaque; and the specimens are of a cubic, rhomboidal, polygonal, or irregular figure. The coloured spars have the property of becoming phosphorescent, or emitting light, when laid upon a hot iron, or otherwise heated; but they lose this property by being made red hot. This spar is not sufficiently hard to strike fire with the steel. It is insoluble in water, and does not effervesce with acids.

Distillation of
the acid.

If the pure fluor, or spar, be placed in a retort of lead, with a receiver of the same metal adapted, and half its weight of vitriolic acid be then poured upon it, the acid of spar will be disengaged in the aerial form by the application of a gentle heat. This acid air readily combines with water; for which purpose it is necessary that the receiver should previously be half filled with that fluid. When experiments are required to be made with the acid in the elastic state, it must be received over mercury.

Distinctive
character.

The distinguishing property which is most eminently, and almost exclusively, possessed by this acid, is that of dissolving siliceous earth. The first experiments upon
it.

it were made with glass vessels, and were attended with the singular phenomenon of an earthy matter being deposited at the instant that the air came in contact with the water in the recipient. Upon examination it was found to be siliceous earth; and subsequent experiments proved that it was obtained by corrosion of the glass, and held in solution by the elastic fluid. This circumstance shews the necessity of using metallic vessels in the distillation.

ACID OF
SPAR.

Siliceous earth
dissolved.

The fluor acid has been successfully used to make etchings on glass, in the same manner as the nitrous acid has long been applied to copper.

Etchings on
glass.

With argillaceous earth it forms a neutral salt, of a gelatinous consistence. With calcareous earth it produces the spar already treated of. With ponderous earth it forms a salt of difficult solution, which effloresces in the air. It readily combines with magnesia, and forms a crystallizable salt: it takes this earth from every other known acid. With the vegetable alkali it affords a fusible deliquescent salt; the solution of which, if sufficiently evaporated, takes a gelatinous appearance. The mineral and volatile alkalis are said to act nearly in the same manner.

Combinations
with earths
and alkalis.

This acid acts scarcely, if at all, upon gold, silver, lead, mercury, tin, antimony, bismuth, or cobalt, though it dissolves their calces. It acts directly upon iron and zinc, with the production of inflammable air; and it likewise dissolves copper in the metallic state, though less easily than when calcined.

—with metals.

C H A P. VII.

OF THE ACID OF AMBER.

AMBER.

Characters of
amber:

AMBER is a hard brittle substance, sometimes perfectly transparent, but mostly semi-transparent, clouded, or opake. It is found of all colours, but chiefly yellow or orange. Some specimens contain insects or leaves. When broken, it presents a polished surface at the place of fracture. It is capable of a good polish, though always of a somewhat greasy feel. By friction it becomes electric, and is the substance in which the operation of electricity was first taken notice of by the ancients. It emits an agreeable smell when rubbed or heated, and melts at a less temperature than is required to cause mercury to boil. With access of air it is inflammable; but by distillation in closed vessels it affords a small portion of water, a concrete sublimate which is the acid of amber, and an oil. A gentle heat is sufficient to raise the acid; and care must be taken to regulate it so as not to drive up the oil, when the acid is required to be had in a state of purity. The acid itself is soluble in twenty-four parts of cold water, and in a much less quantity when boiling hot. The sublimed acid requires to be purified by repeated solutions and crystallizations.

—wherefound. Amber is dug out of the earth in the Prussian dominions in greater plenty than elsewhere; but the best sort is taken out of the sea, or is cast on shore by the waves. From its being found in the earth in the
neigh-

neighbourhood of fossil wood, as well as from other circumstances, it is supposed to be of vegetable origin. Its analysis evidently shews that it consists of an oil rendered concrete by combination with an acid.

AMBER.

The acid of amber combines with the earths, alkalis, and metallic calces. With clay it affords a salt in crystals; with lime and ponderous earth it produces salts of difficult solubility; and with magnesia, a compound resembling gum. With the vegetable and volatile alkalis it forms crystallizable salts, which deliquesce by exposure to the air; but with the mineral alkali it forms a salt whose crystals are consistent. With the calces of the metals it forms crystals which are for the most part permanent.

Combinations
of the acid of
amber.

From its sublimation in the form of flowers, it is evident that it cannot be exhibited in the aëriform state but at a very elevated temperature. No inquiries have been made in the way of decomposing it.

C H A P. VIII.

OF PHOSPHORUS AND ITS ACID.

PHOSPHORIC
ACID.

Native phos-
phorus.

Characters of
phosphorus.

Page 144.

THE phosphoric acid, or its base, abounds in the animal and vegetable as well as the mineral kingdoms. In this last it is found united to lead or iron, but perhaps most abundantly in combination with calcareous earth. It is asserted that there are whole mountains in Spain which consist of a compound of lime and phosphoric acid *. But the acid has been hitherto most commonly obtained from animal substances. Phosphorus is a substance greatly resembling sulphur in colour and consistence, in its usual state of purification; but it is less brittle, and much more inflammable. When very pure, it is of a clear transparent yellow colour. Like sulphur, it burns with two kinds of flame. An heat of about 60° produces the weaker kind of flame, which scarcely affords any sensible degree of warmth. It has the appearance of white fumes in the day light, but is considerably luminous in the dark. If a vessel containing a small piece of phosphorus be surrounded with water gradually heated, the fumes escape more and more rapidly; and when the water is heated to 160° , the phosphorus takes fire, and burns with a strongly vivid and destructive flame.

* Annales de Chimie, i. 196.

This

This substance, remarkable for its extreme combustibility, and the exhibition of flame without heat, was first discovered about the year 1667, by a chemist whose name was Brandt. Another chemist, well known by his writings, whose name was Kunckel, discovered the secret of Brandt by a set of experiments expressly instituted for that purpose. It is to this philosopher that the world has justly given the honour of the discovery. Our eminent Robert Boyle likewise made the discovery upon the same information probably as that of Kunckel; namely, that the phosphorus was produced from urine. It is asserted that a certain dealer in secrets, one Krafft, communicated the process to Boyle*; but it is not probable that a man of such undoubted integrity as Boyle would have communicated the process to the Royal Society as his own, if this had been the case. Neither indeed does the invention appear to be of that magnitude, as not to be easily hit upon by those who were determined to spare no pains nor attention in the pursuit of discovery, as was the case with the chemists of that day, most of whom indulged extravagant hopes. The process of Boyle consisted in nothing more than distilling urine till the last volatile product came over, which is the phosphorus; and he used no other artifice to facilitate the operation, than that of first evaporating the fluid part of the urine until it became of the consistence of syrup. He then mixed this liquid with thrice its weight of fine sand, and exposed the whole to distillation for

PHOSPHORUS.

The discovery of phosphorus; by Brandt, Kunckel,

Defence of Boyle as the inventor.

Process of Boyle.

* Stahl's CCC. Exper. ed. Berolini, Ann. 1731, p. 393.

PHOSPHO-
RUS.

Process for ob-
taining phos-
phorus from
bones.

Phosphoric
glass.

twelve hours, the fire being made as intense as possible for the last six hours. Other processes have since been invented to shorten this operation; but the late discovery of Scheele has superseded them all, on account of its greater expedition and cheapness.

The fixed residue of bones, after burning, consists of the acid of phosphorus united to lime. If therefore this white friable substance be pounded, and passed through a sieve, and a quantity of diluted vitriolic acid be added, less than is sufficient to dissolve the mass, it will then consist of a solution of selenite, with disengaged phosphoric acid. By evaporation of the clear liquid, the selenite separates in crystals; and the decanted liquor, by farther evaporation to dryness, and the application of a considerable heat, affords the phosphoric acid in the form of a white or transparent glass. If this acid be pounded, and mixed with one third of its weight of charcoal, in an earthen retort, it affords phosphorus by distillation.

The phosphoric glass obtained in the first instance from bones, is not sufficiently deprived of calcareous earth to be used in any other process than that of making phosphorus. For this purpose however it is not necessary to bring it to the consistence of glass. The evaporation may be conveniently performed in a copper vessel; and when the fluid has acquired the consistence of syrup, it may be mixed with its own weight of charcoal in powder, and submitted to distillation in a good earthen retort. Instead of applying a receiver, the neck of the retort may be immersed in a basin of water to a small depth; and the phosphorus, as it comes over, will fall in drops to the bottom.

bottom. It is true that in the process thus managed there will be apparently much phosphorus burned by the admission of the common air, which now and then passes into the neck of the retort, whenever the absorption of the water causes its surface to fall below the aperture; but this quantity is really inconsiderable, and is compensated by the simplicity and facility of the process. The operator must be careful that the neck of the retort be not plunged to too great a depth; because in this case the water would pass into the body of the retort at the time of absorption, before the surface of the water in the basin had fallen sufficiently to admit the air. The phosphorus comes over as soon as the retort is red hot; and when the drops cease, the whole apparatus must be suffered to cool. It has the form of reddish wax, or tallow; and may be pressed together under the water while it is yet warm. If this be done with the naked hand, great care must be taken that no particle shall remain sticking to the hands, or under the nails; as such a particle, by taking fire when brought into the air, might produce very painful and disagreeable consequences. It may be moulded into sticks, by putting the pieces into small conical tubes of glass, closed at one end, and fixed upright in a piece of wood, the whole being immersed under water: on heating the water, the phosphorus will melt, and take the desired form. The impurities that rise to the upper ends of the tubes may be cut off when taken out, which must not be done till all is cool.

PHOSPHO-
RUS.Process for ob-
taining phos-
phorus.

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Phosphorus may be had exceedingly pure by straining it through a leather bag immersed in hot water; Purification of phosphorus.

P

or,

PHOSPHORIC ACID. or, which is still better, by distilling it a second time with a very gentle heat. The blackish colour of phosphorus is ascribed to a portion of phosphoric acid which is mixed with it. This disappears almost entirely by boiling with a small quantity of volatile alkali *; and if the phosphorus be boiled two or three successive times in ardent spirit, it becomes perfectly transparent, and of a beautiful opal colour, with very little loss of weight.

Phosphorus must be kept in a bottle of water, to prevent its gradual combustion.

Phosphoric acid obtained by slow combustion. If a number of sticks of phosphorus be placed upright in a glass funnel, a piece of glass tube being previously put into the neck of the funnel to prevent their falling through; and if this funnel be then inserted in the neck of a bottle containing distilled water, the phosphorus will be decomposed by the slow combustion, provided it be exposed to a temperature higher than that of 60° ; and the phosphoric acid will gradually pass through the funnel into the water. The acid thus obtained contains a portion of phosphorus; but, by exposure to the air, this also becomes converted into acid: or the superfluous portion of phosphorus may be burned by causing the acid to boil.

Concrete phosphoric acid. If the water be evaporated from the phosphoric acid, it may be converted by heat into a solid transparent substance, which differs from that obtained immediately from bones by the vitriolic acid, in attracting the humidity of the air, and its solubility in water. It is said however that a stronger heat will render

* Annales de Chimie, i. 234.

it permanent, and deprive it of acidity; which change ^{PHOSPHORIC ACID.} most probably arises from its combining with the earth of the crucible.

Phosphorus may likewise be converted into phosphoric acid by treating it with nitrous acid. In this operation a tubulated retort, with a ground stopper, must be half filled with concentrated nitrous acid, and a gentle heat applied. Small pieces of phosphorus being then introduced through the tube, will be dissolved with an effervescence, which is produced by the escape of a large quantity of nitrous air. This addition of phosphorus must be continued until the last piece remains undissolved. The fire being then raised to drive over the last portions of nitrous acid, the phosphoric acid will be found in the retort; partly in the concrete, and partly in the liquid form.

Vitriolic acid produces nearly the same effect as the nitrous; but, being less volatile, it is less adapted to the purpose.

The strong combustion of phosphorus effects a decomposition nearly complete, and leaves the acid in a dry state.

Phosphoric acid is likewise produced by passing a stream of vital air through phosphorus liquefied in hot water.

Phosphorus combines with the caustic fixed alkalis in a boiling heat, and forms an hepar; during which a peculiar elastic fluid is given out, which possesses the remarkable property of taking fire as soon as it communicates with the air of the atmosphere. This air has evidently the same relation to phosphorus as the common hepatic air has to sulphur; and, like

PHOSPHORIC that, it probably consists of a solution of the phosphorus
ACID. in inflammable air.

Combination of
 phosphorus
 with sulphur :

Sulphur and phosphorus unite by fusion, and form a solid compound of a fetid smell, which burns with a yellow flame, and swells in water ; at the same time communicating acidity to that fluid, and emitting a

—with oils :

smell of hepatic air. All kinds of oils dissolve phosphorus, and are rendered luminous by it : several essential oils form a solution which takes fire by exposure to the air, probably in consequence of the emission of phosphoric air. The butter of wax, which consists of wax deprived of part of its acid by distillation, is said to be the properest material for producing this effect. Very strong ardent spirit dissolves a portion of phosphorus, which gives a perceptible

—ardent
 spirits :

—metals.

light upon the addition of water. Metals do not readily combine with this substance when simply heated with it : but when the phosphoric acid, together with charcoal, is exposed to a strong heat, a considerable number of the metals may be made to unite with it *, probably in consequence of their being previously calcined by the acid.

Metals revived
 by phosphorus.

When a stick of phosphorus is plunged in the solutions of gold, silver, copper, and other metals, the phosphorus becomes gradually covered with a brilliant metallic sheath, the phosphorus becoming acidified as the metal is revived.

Uses of phosphorus.

Phosphorus has not yet been applied to any use, excepting that a few trials have been made of its efficacy in medicine. The luminous appearance of

* Journal d. Physique, for March 1789.

writing made of a stick of phosphorus upon paper, ^{PHOSPHORIC ACID.} or any other substance which can abrade it, is sufficiently known. There is some danger of its catching fire if the friction be swift or violent; and for that reason the stick of phosphorus ought to be held in a metallic case, and a cup of water should be at hand to plunge it in. It is also used when dissolved in essential oils, or butter of wax, to make tapers or matches, intended to supply the place of flint and steel in producing light; but it is not probable that these will ever be afforded sufficiently cheap to answer the purpose of a substitute to that operation. ^{Phosphoric matches.}

The acid of phosphorus exists, as has been already observed, in two states similar to those of the volatile and fixed vitriolic acids: and the difference between these states arises likewise from a similar cause; namely, that a part of the phosphorus is not converted into acid, but is held in solution by that part which is acidified. ^{Two states of phosphoric acid.} Neither of the kinds of phosphoric acid rises totally by heat like the volatile vitriolic acid: but that which contains phosphorus emits white fumes, which seem to consist of part of the acid combined with the redundant phosphorus; and the residue melts into the vitreous form. ^{Page 144. 152.} This difference between the vitriolic and phosphoric acids depends no doubt upon the greater degree of fixity of the latter.

The phosphoric acid does not appear to act upon siliceous earth, though it corrodes glass when hot. It unites with clay in the dry way. ^{Combinations of phosphoric acid.} With calcareous earth it forms a combination scarcely soluble in water, unless there be an excess of acid: it has been already noticed that the earthy residue of bones consists of

PHOSPHORIC
ACID.

this substance. With ponderous earth it forms a salt whose properties are little known; and with magnesia it forms a crystallizable compound of difficult solubility.

Combinations of
phosphoric acid
with alkalis.

This acid, when in combination with the vegetable alkali, forms a very soluble salt, which is suspended in considerably greater quantity in hot than in cold water. It separates from the liquid in crystals, either by cooling or evaporation. The combination of phosphoric acid with mineral alkali constitutes a salt of an agreeable taste, resembling that of common salt. It is not easily crystallized, by reason of its disposition to form an adhesive matter by evaporation, which resembles gum. A small excess of alkali renders it more disposed to crystallize, and causes it to effloresce by exposure to the air. This salt has been lately introduced into medicine. The combination of volatile alkali with phosphoric acid is likewise more soluble in hot than in cold water, and affords crystals by cooling. An excess of alkali renders the crystallization more easy. It is greatly disposed to fly off by a gentle heat.

Phosphoric salts
from urine.

The phosphoric salts were first obtained from urine. This animal fluid consists of a large quantity of water; the acids of phosphorus and of the calculus of the bladder, both in a disengaged state; some common salt, with the saline combinations of the phosphoric acid with lime, mineral alkali, and volatile alkali; and two kinds of extractive matter, one of which is soluble in ardent spirit, and the other in water. When urine is exposed to evaporation by heat, it assumes a darker colour; and a pulverulent matter falls down, which

which consists of the calcareous phosphoric salt, and ^{PHOSPHORIC ACID.} the acid of the human calculus. If the urine be filtered as soon as it has acquired a viscid consistence, it affords saline crystals by cooling. These consist of ^{Salts from urine.} the common salt, and also of a triple combination of phosphoric acid with the mineral and vegetable alkalis, which is generally known by the name of ^{Microcosmic salt.} microcosmic salt. Repeated evaporations and coolings are required to deprive urine of the most part of its salts. Subsequent solution in water, heated and cooled in closed vessels, purifies the phosphoric crystals, and separates the salt with the base of volatile alkali from that which contains mineral alkali. As the former of these salts only is decomposed by heating with charcoal, it is from this alone that the phosphorus of urine is obtained. The combination of mineral alkali with phosphoric ^{Perlate acid.} acid was for some time supposed to be a peculiar acid, and was called the perlate acid.

The microcosmic salt has been applied to great use by the celebrated Bergman, as a flux in blow-pipe experiments.

Phosphoric acid unites with several of the metallic calces. It acts upon oils, to some of which it communicates a peculiar flavour, and it thickens others. ^{Combinations of phosphoric acid with metals and oils.} It has not been well decided whether it can be exhibited in the elastic state at the temperature of the atmosphere.

The saline compounds formed by the phosphoric acid, when not totally acidified, appear to differ from those of the complete acid; but few experiments have been made with these.

The theory of the conversion of phosphorus into ^{Theory.}

PHOSPHORIC
ACID.

Theory.

an acid, and the reduction into its original state by treatment with charcoal, is perfectly similar to that of sulphur and vitriolic acid. When phosphorus is burned, there is an absorption of vital air, at the same time that phlogiston, or the principle of inflammability, is supposed to be extricated. In this manner the phosphorus is converted into an acid, which, when water is not present, has the appearance of white flakes; and in every state weighs considerably more than the phosphorus itself. On the other hand, when phosphoric acid is heated with charcoal, the vital air is absorbed by the latter; at the same time that the phosphoric basis is supposed to receive phlogiston from the charcoal, and by that means recovers its original state. According to the new theory, the phosphorus is considered as a simple substance, relatively to the present state of our knowledge; its conversion into an acid being supposed to consist merely in the absorption of vital air, and its revivification in the disengagement of that substance.

C H A P. IX.

OF THE METALLIC ACIDS; OF ARSENIC, OF MOLYB-
DENA, AND OF TUNGSTEN, OR WOLFRAM.

IN the preceding chapter we have exhibited a number of instances in which the process of combustion has converted inflammable substances into acids: whence it may be inferred, as a general rule, that acidity is the state of a combustible body, which is burned, either completely or nearly so; whether such combustion be made to consist in the disengagement of phlogiston and absorption of pure air, or whether it be stated simply as the latter effect. We have seen that sulphur, which is highly inflammable, becomes converted into vitriolic acid air, which is not at all inflammable; and that, when completely burned, it becomes vitriolic acid, in which the peculiar properties of that class of bodies are most eminently seen. Phlogisticated air, which, by reason of its slight tendency to unite with vital air, appears to require either a long exposure to that substance, or the successive ignition of its parts by electricity, is found to form nitrous air when the combustion is incomplete—a substance which has no acid properties; but which becomes nitrous acid of various degrees of acidity, according to the dose of vital air it may be combined with, and perhaps the extrication of phlogiston. The metals have been shewn to be combustible, as well by the

ACIDITY.

Retrospect of
the facts and
doctrines con-
tained in the
present section.

ACID OF ARSENIC.

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**METALLIC
ACIDS.**

Acidification of
metals.

General infer-
ences; by con-
jecture.

Metals acidified.

Arsenic.

the action of acids, as by heating them with access of pure air. When they are thus calcined, they become soluble in acids. Some of the metallic bodies have been discovered to be susceptible of a farther continuation of the process by which they are calcined; and this continuation is found to change them into acids soluble in water, and disposed to combine with and neutralize alkaline substances. Hence there seem to be certain periods of combustion at which the same simple basis becomes successively converted into a calx, or substance capable of neutralizing acids; and afterwards into one which combines with and neutralizes alkalis. If we might generalize this, it would be fair to conclude that all metals are, in their own nature, capable of being converted into acids; that all acids are reducible to inflammable substances, though art has not yet devised the means of doing it in every instance; and it might be conjectured that the fixed alkalis themselves may consist of combinations of inflammable substances with pure air, to which they may adhere with too strong an affinity to be separated by means of any medium we are acquainted with.

The metallic substances which have been acidified are, arsenic, molybdena, and wolfram.

Arsenic is a substance which combines with and mineralizes many of the metals, and is sublimed from them in the form of a white calx. It is not clearly ascertained, in a number of instances, whether the arsenic be combined with this calx, or with the metal, or with the acid it is capable of being converted into. If this white calx be dissolved in three times its weight of

of boiling muriatic acid in a tubulated retort, and twice its weight of nitrous acid be then added, and the evaporation still continued, the former acid will fly off in the elastic state; while the nitrous acid will be decomposed, and will convert the arsenic into a concrete acid.

METALLIC
ACIDS.

Process for obtaining the arsenical acid.

The purity of this may be ascertained by igniting it; for this degree of heat will drive off any portion of the other acids that may remain.

The arsenical acid is much more fixed in the fire than the calx itself; it may even be fused into a transparent glass. It is slightly deliquescent, and requires twice its weight of water to dissolve it. This acid forms a saline combination with argillaceous earth, which coagulates as soon as it arrives at the point of saturation. With lime it forms a crystallizable salt. With ponderous earth it forms a salt of difficult solubility. With magnesia it produces a coagulum, or gelatinous substance. It does not act upon siliceous earth, unless perhaps in the dry way.

Characters of
arsenical acid.

Combinations
with earths:

The combination of this acid with vegetable alkali forms a deliquescent salt, which does not crystallize; but if there be a small excess of the acid, the solution will afford fine crystals, which are the neutral arsenical salt of Macquer. The mineral alkali, saturated with arsenical acid, affords a crystallizable salt nearly resembling the foregoing. It unites likewise with the volatile alkali, and forms a salt in crystals. When this is exposed to distillation, part of the alkali is decomposed; phlogisticated air is given out; and the acid, being reduced to the calciform state, sublimes.

—with alkalis.

Page 128.

Mere heat in an open vessel gradually reduces the acid of arsenic to the state of calx, which sublimes.

When

**METALLIC
ACIDS.**

Reduction of
arsenical acid.

Combination
with sulphur.

Theory.

When the fluid acid is digested with charcoal powder, no change takes place until the moisture is evaporated; and when the heat is raised to ignition, a sudden combustion takes place, all the acid is reduced and sublimed into the neck of the retort, the greater part being in the form of the metallic regulus, and the rest calx. Continued digestion with oils revives this acid. It unites with sulphur by fusion; the whole mass rising almost instantly in the form of a red sublimate, at the same time that volatile sulphureous acid passes into the receiver.

The theory of these facts will not be difficult to the reader who has attentively considered the preceding chapters. The white calx of arsenic was dissolved in marine acid; because it is required to be had in a state of extreme division, and because the nitrous acid can only dissolve it very sparingly. The nitrous acid is added; because it readily gives out vital air (and perhaps absorbs phlogiston), while it becomes converted into nitrous air, which flies off. The calx of arsenic thus becomes completely acidified. This acid, at a strong temperature, decomposes volatile alkali, which is a compound of phlogisticated and inflammable air. This last principle either affords phlogiston to the acid, and reduces it to the state of a calx; or, according to the new theory, performs the same thing by uniting with the vital air, and forming water. And a similar explanation will serve for the effects of charcoal, or oils, which either afford phlogiston, or absorb the vital air. With respect to the effects of sulphur, part of it is acidified by combustion, or combination with the vital air of the acid, and comes over in the form

form of vitriolic acid air; while the rest combines with the arsenic, which is reduced, but in what degree does not clearly appear.

METALLIC
ACIDS.

Molybdena is a substance which greatly resembles plumbago, or black lead; but its texture is scaly, and it is not easily pulverised, on account of a degree of flexibility which its laminæ possess. If it be triturated in a mortar with vitriolated tartar, this saline substance will, by the hardness and angular figure of its particles, render it more easily pulverable; and when this purpose is accomplished, the salt may be washed away by several affusions of water. If the powder be then placed in a retort, with five or six times its weight of diluted nitrous acid, and distillation be carried on to dryness, it is found that volatile vitriolic acid and nitrous air are extricated, and the colour of the residue becomes lighter. More acid must then be added, and the distillation again repeated till the fourth or fifth time. A strong heat is required to drive off the last portions of vitriolic acid formed by the sulphur. When no more red vapours appear, the residue will be white and pulverulent, resembling chalk. This is the acid of molybdena. It requires near five hundred times its weight of boiling water to dissolve it, and exhibits weak acid properties.

Characters of
molybdena.

Process for ob-
taining the acid
of molybdena.

This acid combines with lime, magnesia, and calcareous earth, with which it forms salts of very difficult solution. When added to a solution of ponderous earth in the nitrous or marine acids, it forms a compound which is sparingly soluble in cold water; and, on that account, falls to the bottom. The combination

Combinations.

tion

METALLIC
ACIDS.

tion of this acid with vegetable alkali is more soluble in water than the acid itself, and affords crystals by evaporation. It unites likewise with the volatile alkali. Several of the metals, when dissolved, are likewise seized by this acid; and precipitated from their solutions.

Regenerated
molybdena.

When the acid of molybdena is heated with sulphur in a retort, placed in such a manner as that the sublimed sulphur may melt and run back again, a combination between these two substances is at length produced; and the superfluous sulphur flies off, being partly converted into volatile vitriolic acid. The residue is found to be in every respect the same as the native molybdena. The analysis of molybdena by the nitrous acid shewed that it consists of sulphur united to a peculiar acid, or acid basis; and this synthetical production of molybdena proves the same thing.

Acid of tung-
sten, or wol-
fram.

The acid of tungsten, or wolfram, is a peculiar metallic substance obtained from these minerals. The tungsten is a ponderous ore, of a grey colour, and lamellar texture. It consists of the metallic calx, or acid, united to about its own weight of calcareous earth. Wolfram is a mineral of still greater specific gravity, which is formed in the tin mines of Cornwall, and elsewhere. It is of a brownish black colour, of a radiated or foliated texture, internally shining almost with the lustre of a metal. It is of a moderate hardness, though sometimes so friable as to be pulverable between the fingers. It contains about two-thirds of the peculiar calx or acid; and the rest

rest consists chiefly of the calces of manganese and iron. If either of these minerals be pulverized and digested in the vitriolic, nitrous, or marine acids (but the latter is the most effectual), the calcareous earth of the tungsten, or the manganese and iron of the wolfram, which lie on the external surfaces of the particles, will be dissolved; and the wolfram calx, being laid bare, will exhibit a yellow colour. The residuum, afteredulcoration, or washing with water, being digested with volatile alkali, the wolfram calx, or acid, will be taken up, or extracted from the surface, in the same manner; the yellow colour vanishing at the same time. This residue, afteredulcoration, will again present a surface to be acted upon by the marine acid, which will seize another stratum of particles, that in the former digestion were defended by the wolfram calx, which was afterwards taken up by the volatile alkali. In this manner, by the alternate application of volatile alkali and marine acid, the mineral will at length be almost entirely dissolved. The portions of acid are found to contain either the calces of manganese and iron, or else calcareous earth, according to the mineral made use of; and the alkaline solvent contains the acid of wolfram. The addition of nitrous acid to this last fluid precipitates a salt which has acid properties, and is sparingly soluble in water. The first discoverer * called it the acid of tungsten, though in fact it contains both volatile alkali and nitrous acid. It may however be deprived of these last by calcination, and is then of a brimstone yellow colour.

METALLIC
ACIDS.

Process for obtaining the acid of tungsten, or wolfram.

* Scheele.

METALLIC
ACIDS.

The yellow colour produced by applying marine or nitrous acid in a digesting heat, affords an easy method of distinguishing such minerals as contain wolfram.

Process for obtaining the acid of tungsten, or wolfram.

In the dry way, if the vegetable alkali be fused with either of these minerals, it takes up the calx or acid. This being dissolved in water, filtered, and evaporated to dryness, must be boiled in nitrous acid on a sand bath. The acid takes up the alkali, and may be decanted off. A repetition of this boiling for two or three times with fresh acid, will effectually carry off the whole of the alkali; and the adhering acid may be driven off by calcination in a cupelling furnace. The powder is then yellow, and does not differ from that obtained by the distillation of volatile alkali in the moist way.

Characters of the acid.

This matter is not soluble in water; but when triturated in that fluid it forms an emulsion, which passes through the filtre, and does not completely subside in the course of three months. This does not form an emulsion with acids. Pure vegetable alkali dissolves it, as has been already observed; but the produce has always an excess of alkali. If more nitrous acid be added than is sufficient to saturate the alkali, a precipitate falls down, which consists of acid, alkali, and wolfram calx. The addition of lime to this, or to the precipitate from volatile alkali, produces a regenerated tungsten, or combination of lime with the wolfram calx or acid; and the alkali, together with the nitrous acid, is found in the supernatant fluid.

It is seen * therefore that this yellow matter is either METALLIC
an acid, or in a state nearly approaching to acidity: ACIDS.
for it is not combinable with acids, and unites readily
to alkalis and calcareous earth.

Arfenic, molybdena, and wolfram, are reducible to the metallic state, and will again come under our inspection when we treat of that class of bodies.

* The best account of this substance is to be found in "De Luyart's Chemical Analysis of Wolfram," of which a translation was printed in London, 1785, with Scheele and Bergman's papers prefixed.

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BOOK II.

PARTICULAR CHEMISTRY.

SECTION III.

OF METALLIC BODIES.

CHAP. I.

CONCERNING GOLD.

GOLD is a yellow metal, of much greater specific gravity than any other body in nature, except platina. It is soft, very tough, ductile, and malleable; unalterable and fixed, whether exposed to the atmosphere, or to the strongest heat of furnaces. The most powerful burning mirrors are said to have volatilized it; and it has been driven up in fumes, in the metallic state, by flame urged upon it by a stream of dephlogisticated air. The electric shock converts it into a purple calx, as may be seen by transmitting

GOLD.

Characters of gold.

GOLD. that commotion through gold leaf between two plates of glass; or by causing the explosive spark of three or more square feet of coated glass to fall upon a gilded surface. A strong heat is required to melt it, which does not happen till after ignition. Its colour when melted is of a blueish green; and the same colour is exhibited by light transmitted through gold leaf.

Obvious properties.

Extreme ductility and tenacity. The limits of the ductility and malleability of gold are not known; and its tenacity exceeds that of any other metal. A gold wire, of one tenth of an inch diameter, requires 500lb. weight to break it.

Manufacture of gold leaf:

The method of extending gold, used by the gold-beaters, consists in hammering a number of thin rolled plates between skins or animal membranes. By the weight and measure of the best wrought gold leaf, it is found that one grain is made to cover $56\frac{3}{4}$ square inches; and from the specific gravity of the metal, together with this admeasurement, it follows, that the leaf itself is $\frac{1}{282000}$ part of an inch thick. This however is not the limit of the malleability of gold; for the gold-beaters find it necessary to add three grains of copper in the ounce to harden the gold, which otherwise would pass round the irregularities of the newest skins, and not over them; and in using the old skins, which are not so perfect and smooth, they proceed so far as to add twelve grains. The wire which is used by the lace-makers is drawn from an ingot of silver, previously gilded. In this way, from the known diameter of the wire, or breadth when flattened; and its length, together with the quantity of gold used; it is found by computation, that

Gilt wire.

that the covering of gold is only $\frac{1}{12}$ part of the thickness of gold leaf; though it still is so perfect as to exhibit no cracks when viewed by a microscope.

GOLD.

No acid acts readily upon gold but aqua regia and the dephlogisticated marine acid. The vitriolic acid distilled from manganese has some action upon it; as have likewise the pale nitrous acid, and the phosphoric acid when boiling.

Solvents.

The small degree of concentration which the dephlogisticated marine acid is susceptible of, and the imperfect action of the latter acids, render aqua regia the most convenient solvent for this metal.

Aqua regia.

When gold is immersed in aqua regia, an effervescence takes place with the escape of air, which has not been examined; the solution tinges animal matters of a deep purple, and corrodes them. By careful evaporation, fine crystals of a topaz colour are obtained. The gold is precipitated from its solvent by a great number of substances. Lime and magnesia precipitate it in the form of a yellowish powder. Alkalis exhibit the same appearance; but an excess of alkali redissolves the precipitate. The precipitate of gold obtained from aqua regia by the addition of a fixed alkali, appears to be a true calx, and is soluble in the vitriolic, nitrous, and marine acids; from which however it separates by standing, or by evaporation of the acids. The nut gall precipitates gold of a reddish colour, very soluble in the nitrous acid, to which it communicates a fine blue colour.

Solution of gold.

Precipitates:
—by earths
and alkalis:

The volatile alkali precipitates the solution of gold much more readily than fixed alkalis. This precipitate, which is of a brown, yellow, or orange colour,

—volatile alkali.

GOLD.
 Production of
 fulminating
 gold :

possesses the property of detonating with a very considerable noise when gently heated. It is known by the name of fulminating gold. The presence of volatile alkali is necessary to give the fulminating property to the precipitate of gold ; and it will be produced by precipitating it by fixed alkali from an aqua regia previously made by adding sal ammoniac to nitrous acid, or by precipitating the gold from pure aqua regia by means of sal ammoniac instead of the volatile alkali alone. The fulminating gold weighs one fourth more than the gold made use of. A considerable degree of precaution is necessary in preparing this substance. It ought only to be dried in the open air, at a distance from a fire, because a very gentle heat may cause it to explode. Several fatal accidents have arisen from its explosion, in consequence of the friction of ground stoppers in bottles containing this substance, of which a small portion remained in the neck.

Analysis.

Page 50.

Fulminating gold, when exposed by Berthollet to a very gentle heat in a copper tube, with the pneumatical apparatus of mercury, was deprived of its fulminating quality, and converted into a calx, at the same time that alkaline air was disengaged. From this dangerous experiment it is ascertained that fulminating gold consists of calx of gold, combined with the volatile alkali. The same eminent philosopher caused fulminating gold to explode in copper vessels. Phlogisticated air was disengaged, a few drops of water appeared, and the gold was reduced to the metallic form. From this experiment he infers that the volatile alkali was decomposed ; that the phlogisticated air, suddenly

denly assuming the elastic state, caused the explosion ; GOLD.
 while the vital air of the calx united with the inflammable air of the alkali, and formed the water.

This satisfactory theory was still further confirmed Theory.
 by that decomposition of fulminating gold, which takes place in consequence of the action of the concentrated vitriolic acid, of melted sulphur, fat oils, and ether; all which deprived it of its fulminating quality by combining with its volatile alkali.

Liver of sulphur precipitates gold from its solvent ; Precipitation of gold by liver of sulphur :
 the alkali uniting with the acid, and the gold falling down, combined with the sulphur; of which however it may be deprived by moderate heat.

Most metallic substances precipitate gold from aqua —by metallic substances.
 regia; lead, iron, and silver precipitate it of a deep and dull purple colour; copper and iron throw it down in its metallic state; bismuth, zinc, and mercury, likewise precipitate it. A plate of tin immersed in a solution of gold affords a purple powder, called “the purple powder of Cassius,” which is used to paint in enamel. There are various methods of managing this process. That described by Macquer consists in Process for making the purple powder of Cassius.
 dissolving tin by very small portions at a time without heat, in an aqua regia composed of two parts of nitrous, and one of marine acid, previously weakened with water equal in weight to both the acids. The first small portion of tin must be suffered to be entirely dissolved before a second is added. This addition must be continued till the acid has acquired a yellow colour, and scarcely acts at all upon the tin last added.

GOLD.
 Process for
 making the
 purple powder
 of Cassius.

On the other hand, the purest gold must be dissolved in an aqua regia composed of three parts of nitrous and one of marine acid. This solution may be made as expeditiously as the operator chooses by the assistance of the heat of a sand bath.

The solution of tin must then be largely diluted; as, for example, with one hundred parts of distilled water; and a small quantity of this may then be assayed by separating it into two parts, and diluting one of the parts still farther. Upon trial of both, by letting fall a drop of the solution of gold into each, it will be seen which affords the most beautiful purple precipitate. The whole of the solution of tin must accordingly be altered, if necessary, by adding more water. Pour into this solution, in a large glass or earthen vessel, nearly half as much of the solution of gold as it contains of solution of tin, stirring the mixture with a glass stick. In a short time the liquor will become of a beautiful red colour, which will gradually disappear by the subsidence of the precipitate. By adding a small quantity of solution of tin, it will be seen whether the whole of the gold is precipitated. The clear liquor must then be decanted, and the precipitate washed. It consists of the calces of gold and tin in combination, and is the only known substance which has the property of communicating a purple colour to glass.

Observations.

The difficulties attending the preparation of this article appear to depend on the state of the tin. If the solution of this metal be made with heat and rapidity, it becomes too much calcined to adhere to
 the

the acid, or to precipitate the gold; and the combination of the two metals which falls down, varies in colour accordingly as this term is approached. These are the chief circumstances; but there is no doubt that a complete examination of the process would indicate others worthy of notice.

Ether, naptha, and essential oils, take gold from its solvent, and form liquors which have been called potable gold. The gold which is precipitated by evaporation of these fluids, or by the addition of martial vitriol to the solution of gold, is of the utmost purity.

In the dry way, gold resists the action of neutral salts, more especially nitre, which deflagrates with the imperfect metals. Nitre however does not afford an expeditious way of purifying gold, because this metal in some measure protects and covers the alloys from its action. It is remarked that borax, used as a flux with gold, renders it paler; and that this alteration of colour disappears by the addition of nitre, or common salt. As the acid of borax forms a compound with gold, which falls to the bottom when this acid is added to the metal in solution, it is probable that the paleness produced by borax may arise from the combination of a small portion of its acid with the gold, which might be driven off by a continuance of the heat; and unites by stronger affinity with the alkali of the nitre, or of the common salt, in proportion as their acids are dissipated by heat.

Earths and alkalis do not act on gold in the dry way. Sulphur, which combines with most metals, has no effect on this. A process called dry parting

GOLD.

Solutions of gold in ether, &c.

Gold resists nitre:

—but is rendered pale by borax:

—unchanged by earths, alkalis, or sulphur.

is

GOLD. is grounded on this property, and is more especially used in separating silver from gold, when the quantity of this latter metal is too small to answer the charges of dissolving the larger mass of silver in nitrous acid. For this purpose, the mixed metal is fused, and flowers of sulphur thrown on its surface. This combines with the silver in the form of a black scoria; while the gold remains at the bottom in its metallic state. The operation of dry parting does not leave the gold in a state of purity; because the last portions of silver are defended from the action of the sulphur. But when the quantity of silver is thus diminished, the operation of parting with aqua fortis, or nitrous acid, may be advantageously used.

Combination
with liver of
sulphur:

Liver of sulphur dissolves gold in the dry way. Equal parts of sulphur and vegetable alkali are to be hastily fused with one fourth of a part of gold leaf. This combination is soluble in water, with which it forms a yellowish green solution. By the addition of an acid the gold is thrown down in combination with the sulphur; of which it may be deprived by heat.

—with metals.

Most metals unite with gold by fusion. With silver it forms a compound, which is paler in proportion to the quantity of silver added. It is remarkable that a certain proportion, for example a fifth part, renders it greenish. From this circumstance, as well as from that of a considerable proportion of these metals separating from each other by fusion, in consequence of their different specific gravities, when their proportions do not greatly differ, it should seem that their union is little more than a mere mixture, without combination.

tion. For as gold leaf transmits the green rays of light, it will easily follow, that particles of silver, enveloped in particles of gold, will reflect a green instead of a white light. GOLD.

A strong heat is necessary to combine platina with gold; it greatly alters the colour of the gold if its weight exceed the forty-seventh part of the mass: it does not much affect the ductility. The Spanish ministry has prohibited the exportation of platina from America, lest it should be used in adulterating gold; but this does not appear to be a danger which need be feared, as chemistry has long been in possession of several simple and expeditious methods of distinguishing this fraud, which besides is evident to the sight when the quantity of debasement is considerable. It may be questioned, likewise, whether the value of platina would not soon exceed that of gold, if its properties and uses were better known in society.

Mercury is strongly disposed to unite with gold in all proportions, with which it forms an amalgam: this, like other amalgams, is softer, the larger the proportion of mercury. It softens and liquefies by heat, and crystallizes by cooling.

Lead unites with gold, and considerably impairs its ductility. Copper renders gold less ductile, harder, more fusible, and of a deeper colour. This is the usual addition in coin, and other articles used in society. Tin renders it brittle in proportion to its quantity; but it is a common error of chemical writers to say that the slightest addition is sufficient for this purpose. With iron it forms a grey mixture, which obeys the magnet. This metal is very hard, and is said

Combinations
with metals.
Platina.

Vide p. 233,
and also chap.
iii. of this sec-
tion.

—lead, copper,
&c.

Alchorne in
Phil. Transf.
vol. lxxv.

GOLD.
 Combinations
 with metals.

said to be much superior to steel for the fabrication of cutting instruments. Bismuth renders gold white and brittle; as do likewise nickel, arsenic, and antimony. Zinc produces the same effect; and, when equal in weight to the gold, a metal of a fine grain is produced, which is said to be well adapted to form the mirrors of reflecting telescopes, on account of the fine polish it is susceptible of, and its not being subject to tarnish. The alloys of gold with the regulus of manganese or molybdena are not known. It could not be mixed with the regulus of wolfram, on account of the infusibility of this last substance.

Native ores, or
 alloys of gold.

Gold is found mostly in the metallic state, though generally alloyed with silver, copper, iron, or all three. It is found either in separate lumps, or visible grains, among the sands of rivers in many parts of Europe, and elsewhere. The quantity is for the most part insufficient to pay the cost of separating it; but it is thought to be more universally diffused in sands and earths than any other metal, except iron. The greatest quantity of gold is imported into Europe from South America. Some is brought from the East Indian islands and China, and some from the coast of Africa. The principal gold mines in Europe are those of Hungary. Some sands afford gold by simple washing; the heavy metallic particles subsiding soonest; but when it is bedded in earths or stones, these substances are pounded, and boiled with one tenth of their weight of mercury, together with water. The mercury, after a certain time, absorbs the gold, and may be separated by pressure through leathern bags, and subsequent distillation. Or otherwise, if the sand be heated

Purification.

red hot, and quenched in water several times, for the purpose of cracking and dividing it, and the whole be then melted into glass, with twice its weight of the calx of lead, called litharge, and charcoal powder be then added, the lead will be revived into the metallic state, and will carry the gold along with it. By exposure to a proper degree of heat, with access of air, the lead may again be converted into litharge, and the gold will be left pure. This last operation is in fact a method of assaying sands which contain gold, rather than of obtaining it from them in the large way.

GOLD.
 Auriferous
 sands.

Gold is also found in certain martial pyrites in Sweden and elsewhere; from which it may be extracted by torrefaction, or burning of the sulphur, and subsequent digestion in aqua regia.

Pyrites containing gold.

To obtain gold in a state of purity, or to ascertain the quantity of alloy it may contain, it is exposed to a strong heat, together with lead, in a porous crucible. This operation is called cupellation, and is performed as follows: The precious metal is put, together with a due proportion of lead, into a shallow crucible made of burned bones, called a cupel; and the fusion of the metals is effected by exposing them to a considerable heat in a muffle, or small earthen oven, fixed in the midst of a furnace. The lead continually vitrifies, or becomes converted into a glassy calx, which dissolves all the imperfect metals. This fluid glass, with its contents, soaks into the cupel, and leaves the precious metal in a state of purity. During the cupellation, the scorix running down on all sides of the metallic mass produce an appear-

Cupellation of gold.

GOLD.

appearance called circulation; by which the operator judges whether the process is going on well. When the metal is nearly pure, certain prismatic colours flash suddenly across the surface of the globule, which soon afterward appears very brilliant and clean: this is called the brightening, and shews that the separation is ended.

Separation of
gold from the
perfect metals:

After gold has passed the cupel, it may still contain either of the other perfect metals, platina or silver. The former is seldom suspected; the latter is separated by the operations called quartation and parting. Quartation consists in adding three parts of silver to the supposed gold, and fusing them together; by which means the gold becomes one fourth of the mass only. The intention of this is to separate the particles of gold from each other, so that they may not cover and defend the silver from the action of the pure nitrous acid, which is to be used in the process of parting.

—by quartation:

—and parting. Parting consists in exposing the mass, previously hammered, or rolled out thin, to the action of boiling aqua fortis of a due strength. If the acid be not too concentrated, it dissolves the silver, and leaves the gold in a porous mass of the original form; but, if too strong, the gold is in a powdery form, which may be washed and dried. The weight of the original metal before cupellation, and after all the subsequent stages, serves to ascertain the degree of fineness of the ingot, or ore, of which it was a part.

Fineness of
gold.

The quantity of alloy is never considered as part of the value of metals which contain either gold or silver. In estimating or expressing the fineness of gold, the whose mass spoken of is supposed to weigh twenty-four

four carats of twelve grains each, either real or merely proportional, like the assayer's weights; and the pure gold is called fine. Thus, if gold be said to be 23 carats fine, it is to be understood, that in a mass weighing 24 carats the quantity of pure gold amounts to 23 carats.

GOLD.

In such small works as cannot be assayed by scraping off a part and cupelling it, the assayers endeavour to ascertain its quality, or fineness, by the touch. This is a method of comparing the colour and other properties of a minute portion of the metal with those of certain small bars whose composition is known. These bars are called touch-neededles; and they are rubbed upon the black basalt, which for that reason is called the touchstone. Black flint, or pottery, will serve the same purpose. Sets of golden needles may consist of—pure gold; pure gold $23\frac{1}{2}$ carats, with half a carat silver; 23 carats gold, with one carat silver; $22\frac{1}{2}$ carats gold, with $1\frac{1}{2}$ carat silver; and so forth, till the silver amounts to four carats; after which the additions may proceed by whole carats. Other needles may be made in the same manner, with copper instead of silver; and other sets may have the addition consisting either of equal parts silver and copper, or such proportions as the occasions of business require.

The assay of small work, by the touch.

Touch-neededles.

In foreign countries, where trinkets and small work are required to be submitted to the assay of the touch, a variety of needles are necessary; but they are not much used in England. They afford however a degree of information which is more considerable than might at first be expected. The attentive assayer not only compares the colour of the stroke made upon the

Observations on the assay by the touch.

GOLD.
 Assay by the
 touch.

the touchstone by the metal under examination with that produced by his needle, but will likewise attend to the sensation of roughness, dryness, smoothness, or greasiness, which the texture of the rubbed metal excites when abraded by the stone. When two strokes perfectly alike in colour are made upon the stone, he may then wet them with aqua fortis, which will affect them very differently if they be not similar compositions: or the stone itself may be made red-hot by the fire, or by the blow-pipe, if thin black pottery be used; in which case the phenomena of calcination will differ according to the nature and quantity of the alloy.

Assay of gold
 ores in the
 moist way.

Gold ores may be assayed in the moist way by pounding them very fine, weighing a determinate portion, and attempting their solution in nitrous acid, which will dissolve the matrix if it consist of calcareous earth; or, if it be selenite, the powder may be digested in aqua regia as long as any metallic substance is taken up; after which the gold may be precipitated by an addition of vitriol of iron, which will cause it to fall down in the metallic state.

Uses of gold.

The principal use of gold is as the medium of exchange in coin; for which it has been chosen to occupy the first place, on account of its scarcity, its great weight, and its not being subject to tarnish. The gold coins of Great Britain contain eleven parts of gold, and one of copper.

Gold is likewise used in gilding; for which purpose, as we have already shewn, it is mechanically divided into leaves of extreme thinness. These are stuck upon wood, previously smeared with adhesive oil, or animal glue,

glue, called size. The process called water-gilding, ^{GOLD.} which is usually applied to copper or brass, is performed by immersing the clean copper into a diluted solution of mercury. The copper is corroded by the acid, which at the same time deposits a thin coating of mercury. This coating, after the piece is washed, facilitates the adhesion of an amalgam of gold, which is then to be rubbed upon it. The mercury is afterwards volatilized by heat; and the work is finished by burning gilding wax upon it, which is a composition of red bole, verdigrise, alum, and bees wax. The intention of this last application appears to be that of concealing the defects of the gilding.

There is another method of gilding, which is performed by steeping linen rags in a solution of gold. These are afterwards dried and burned to ashes, which contain gold in a very divided state. Nothing more is necessary than to moisten the end of a cork, and dip it in this burned matter, together with a little wood-ashes, and rub it upon the face of the silver intended to be gilded. By this means the gold easily adheres.

The other uses of gold, in laces, &c. are sufficiently known.

C H A P. II.

CONCERNING SILVER.

SILVER.
 Characters of
 silver.

SILVER is the whitest of all metals, considerably harder than gold, very ductile and malleable, but less malleable than gold; for the continuity of its parts begins to break when it is hammered out into leaves of about the hundred and sixty thousandth of an inch thick, which is more than one third thicker than gold leaf: in this state it does not transmit the light. Its specific gravity is moderate, being inferior to platina, gold, mercury, and lead. It ignites before melting, and requires a strong heat to fuse it. The heat of common furnaces is insufficient to calcine it: but the heat of the most powerful burning lenses vitrifies a portion of it, and causes it to emit fumes; which, when received on a plate of gold, are found to be silver in the metallic state. It has likewise been partly calcined by twenty successive exposures to the heat of the porcelain furnace at Sèvres. The air alters it very little; though it is disposed to obtain a thin purple or black coating from the sulphureous vapours which are emitted from animal substances, drains, or putrefying matters. This coating, after a long series of years, has been observed to scale off from images of silver exposed in churches; and was found, on examination, to consist of silver united with sulphur.

Silver is soluble in the vitriolic acid when concentrated and boiling, and the metal in a state of division. The marine acid scarcely acts upon it, unless dephlogisticated: but the nitrous acid dissolves it with great rapidity, and with a plentiful disengagement of nitrous air; which, during its extrication, gives a blue or green colour to the acid, that entirely disappears if the silver made use of be pure: if it contain copper, the solution remains greenish; and if the acid contain either vitriolic or marine acid, these combine with a portion of the silver, and form scarcely soluble compounds, which fall to the bottom. If the silver contain gold, this metal separates in blackish coloured flocks. The nitrous acid dissolves more than half its weight of silver; and the solution is very caustic, that is to say, it destroys and corrodes animal substances very powerfully. This action appears to depend on the strong disposition of the silver to become revived; by which it either attracts phlogiston from those substances according to the ancient theory, or communicates vital air to them according to the new theory: so that the animal substances undergo a process equivalent to combustion.

The solution of silver, when fully saturated, deposits thin crystals as it cools, and also by evaporation. These are called lunar nitre, or nitre of silver. A gentle heat is sufficient to fuse them, and drive off their water of crystallization. In this situation it is of a black colour, may be cast into small sticks in a mould, and then forms the lapis infernalis, or lunar caustic, used in surgery. A stronger heat decomposes

SILVER.

Solubility of silver in acids.

Combination with nitrous acid.

SILVER. lunar nitre, the acid flying off, and the silver remaining pure. It is obvious that, for the purpose of forming the lunar caustic, it is not necessary to suffer the salt to crystallize, but that it may be made by evaporating the solution of silver at once to dryness; and as soon as the salt is fused, and ceases to boil, it may be poured out. The nitrous acid driven off from lunar nitre is decomposed, the products being vital air and phlogisticated air.

Although the nitrous acid dissolves silver with such great facility, it appears to do this only in consequence of its great power to calcine the metal; for the vitriolic and marine acids have a greater attraction for the calx. They accordingly take it from that acid, and form salts; which, as we have already observed, fall to the bottom on account of their difficult solubility. The vitriol of silver, which is formed by pouring vitriolic acid into the nitrous solution of silver, is sparingly soluble in water, and on that account forms crystals, which are so small that they compose a white powder. The marine acid precipitates from nitrous acid the saline compound called luna cornea, or horn silver, which has been so distinguished because, when melted and cooled, it forms a semi-transparent and partly flexible mass, resembling horn. It is supposed that a preparation of this kind has given rise to the accounts of malleable glass.

If any salt with base of alkali, containing the marine acid, be added to the nitrous solution of silver, the same effect takes place by double affinity; the alkaline base uniting with the nitrous acid, and the silver falling down in combination with the marine acid.

Since

Since the marine acid throws down only silver, lead, and mercury, and the latter of these two are not present in silver that has passed cupellation, though a small quantity of copper may elude the scorification in that process, the silver which may be revived from luna cornea is purer than can readily be obtained by any other means. When this salt is exposed to a low red heat, its acid is not expelled; and a greater heat causes the whole concrete either to rise in fumes, or to pass through the pores of the vessel. To reduce it, therefore, it is necessary that it should be triturated with its own weight of fixed alkali and a little water, and the whole afterwards exposed to heat in a crucible whose bottom is covered with mineral alkali; the mass of luna cornea being likewise covered with the same substance. In this way the acid will be separated from the silver, which is reduced to its metallic state.

SILVER.

Very pure silver obtained from luna cornea.

As the precipitate of luna cornea is very perceptible, the nitrous solution of silver is used as a test of the presence of marine acid in waters; for a drop of this solution poured into such waters will cause a very evident cloudiness. The solution of silver is also used by assayers to purify the nitrous acid from any admixture of marine acid. In this state they call it precipitated aqua fortis.

Test of marine acid in waters.

Purification of nitrous acid.

The precipitates of silver which are formed by the addition of alkalis or earths, are all reducible by mere heat, without the addition of any combustible substance. The fulminating combination of volatile alkali with silver, exhibits one of the most astonishing

Precipitates.

SILVER. instances of chemical detonation hitherto known*.

Preparation of fulminating silver. Pure silver is dissolved in pale nitrous acid, and precipitated by the addition of lime-water. This calx, or precipitate, after decantation of the fluid, is to be dried by exposure to the air for three days. The inventor thinks the presence of light has some influence in the success of the experiment. The dried calx being agitated or stirred in a solution of caustic volatile alkali, assumes the form of a black powder, from which the fluid is to be decanted, and the black substance left to dry in the air. This is the fulminating silver.

Its effects.

Gunpowder and fulminating gold are not to be compared with this new product; as the former requires ignition, and the latter a sensible degree of heat, to cause them to fulminate. But the slightest agitation or friction is sufficient to cause the fulminating silver to explode. When it is once obtained, it can no more be touched. The falling of a few atoms of this preparation from a small height produced the detonation; a drop of water falling upon it had the same effect. No attempts therefore can be made to inclose it in a bottle; but it must remain in the capsule wherein, by evaporation, it obtained this terrible property.

Precautions.

To make this experiment with safety, it is proper to use no greater quantity than a grain of silver; the last desiccation should be made in a metallic vessel; and the face of the operator should be defended by

* Discovered by Berthollet. See the Journal de Physique for June 1788, p. 474.

a mask,

a mask, with holes for the eyes defended with strong SILVER.
glafs.

The volatile alkali made use of in converting the calx of silver into the black precipitate, was exposed to ebullition in a small matrafs of glafs; and the fluid being then suffered to cool, the inside of the vessel became lined with small crystals. When one of these was touched beneath the cold liquid, an explosion took place, which broke the matrafs in pieces, and threw the liquid up to the ceiling of the laboratory.

The inventor's theory of these effects is the same as that of fulminating gold. The combination consists of volatile alkali and calx of silver; that is to say, in the new theory, of inflammable air, phlogisticated air, silver, and vital air. The slightest change of temperature or agitation disposes the inflammable air to combine with the vital air, which adheres very feebly to the silver. These form water, while the phlogisticated air is disengaged, and the silver reduced to the metallic state. The explosion depends on the sudden transition of the phlogisticated air and the water to the elastic state by heat: but the change of capacity from which the heat arises has not yet been explained. On the phlogistic theory, it will be said that the silver is revived by combining with the inflammable air, or phlogiston of the alkali; while the phlogisticated and vital air fly off in the explosion.

It is a valuable discovery of Mr. Keir *, that a mixture of strong vitriolic acid with the nitrous acid, or nitre, is a powerful solvent of silver, though it scarcely

Fulminating
silver.

Theory of the
inventor,
page 231:

—by the phlo-
gistic hypothe-
sis.

Keir's com-
pound acid,
page 174.

* Phil. Trans. 1780, p. 367.

SILVER.

acts upon the other metals. This is of considerable importance in the Birmingham manufactures, where the silver in the cuttings of plated copper is required to be separated from this last metal. For this purpose the pieces of metal are put into a glazed earthen pan, and a composition of eight or ten pounds of oil of vitriol, with one pound of nitre, is poured upon them, stirred about, and the action of the fluid assisted by a heat between 100° and 200° of Fahrenheit. When the liquor is nearly saturated, the silver is to be precipitated by common salt, which may be easily afterwards reduced; or, otherwise, the silver may be precipitated in its metallic state by adding to the solution a few of the pieces of copper, and a sufficient quantity of water, which enables the liquor to act on the copper. The theory of this effect still remains to be investigated.

Sulphur combines readily with silver in the dry way; but may be separated by a stronger heat. The sulphur of liver of sulphur likewise blackens silver, and combines with it, whether the silver be immersed in the liquid solution, or exposed to hepatic air.

Action of aqua
regia upon
silver.

Aqua regia acts strongly on silver; but precipitates it in the form of luna cornea as fast as it is dissolved. This effect may be easily understood by considering that the nitrous acid dissolves the silver, and the marine precipitates it.

The neutral salts alone do not alter silver either in the moist or dry way; nitre, in particular, does not deflagrate with this metal.

Precipitation
of silver by
metals.

Most metallic substances precipitate silver in the metallic state from its solution. The assayers make
use

use of copper to separate the silver from the nitrous acid used in the process of parting. The precipitation of silver by mercury is very slow, and produces a peculiar symmetrical arrangement, called the tree of Diana. In this, as in all precipitations, the peculiar form may be affected by a variety of concomitant circumstances; for which reason one process usually succeeds better than another. Lemery directs that an ounce of fine silver be dissolved in a sufficient quantity of very pure and moderately strong nitrous acid; that this solution be mixed in a matras, or bottle, with about twenty ounces of distilled water; and that, after the addition of two ounces of mercury, the whole be suffered to repose. During the space of forty days a kind of tree of silver will be formed on the surface of the mercury, with branches greatly resembling a vegetable substance in its ramifications. The foregoing process is said by Macquer to succeed very well; but the following, of Homberg, is much shorter.

SILVER.

Tree of Diana.

Process of Lemery.

Make an amalgam, without heat, of four drams of leaf silver, with two drams of mercury. Dissolve this amalgam in four ounces, or a sufficient quantity of pure nitrous acid of a moderate strength; dilute this solution in about a pound and a half of distilled water; agitate the mixture, and preserve it for use in a glass bottle, with a ground stopper. When this preparation is to be used, the quantity of one ounce is put into a phial, and the size of a pea of an amalgam of gold or silver, as soft as butter, is to be added; after which the vessel must be left at rest. Soon afterwards small filaments appear to issue out of the ball

Homberg's process for making the tree of Diana,

SILVER.

ball of amalgam, which quickly increase, and shoot out branches in the form of shrubs.

Theoretical
observations.

Page 81.

In the above experiment of Lemery the nitrous acid deposits its silver at the same time that it takes up mercury; and in consequence of the liquor being so much diluted, the process goes on slowly, and the precipitated silver has time to arrange itself according to the law of its crystallization, whether that depend on the polarity of its particles, or on any other property not yet explained. In the method of Homberg there are two circumstances which appear calculated to forward the process: in the first place, the nitrous acid already contains mercury in solution, which may probably render it more disposed to part with the silver; and, in the next place, the mercury is combined with silver or gold in the form of an amalgam. These may perhaps facilitate the precipitation of the silver, by presenting a base for it to combine with; which may be more perfectly at repose, because less agitable than the fluid mercury in the former experiment. After all, however, though the general theory of the experiment is not difficult, yet it does not seem easy to point out the effectual cause of the differences between the two results.

Combinations
of silver; with
gold:

—with platina.

Silver unites with gold by fusion, and forms a pale alloy, as has been already mentioned in treating of that metal. With platina it forms a hard mixture, rather yellower than silver itself, and of difficult fusion. The two metals do not unite well. Silver melted with one tenth part of crude platina, from which the ferruginous particles had been separated by a strong magnet, could not be rendered clear

clear of scabrous parts, though it was repeatedly fused, poured out, and laminated between rollers. It was then fused, and suffered to cool in the crucible, but with no better success. After it had been formed, by rolling and hammering, into a spoon for blow-pipe experiments, it was exposed to a low red heat, and became rough, and blistered over its whole surface. The quantities were one hundred grains of silver, and ten grains of platina. Nitre was added during the fusions.

SILVER.

Silver very readily combines with mercury. A very sensible degree of heat is produced when silver leaf and mercury are kneaded together in the palm of the hand. With lead it forms a soft mass, less sonorous than pure silver. With copper it becomes harder and more sonorous, at the same time that it remains sufficiently ductile. This mixture is used in the British coinage. Fifteen parts of silver, alloyed with one of copper, form the compound called standard silver. The mixture of silver and iron has been little examined. With tin it forms a compound which, like that of gold with the same metal, has been said to be brittle, however small the proportion; though there is probably as little foundation for the assertion in the one case as in the other. With bismuth, arsenic, zinc, and antimony, it forms brittle compounds. It does not unite with nickel. The compound of silver and wolfram in the proportion of two of the former to one of the latter, was extended under the hammer during a few strokes; but afterwards split in pieces.

Combinations
of silver with
mercury:

—with lead:

—with copper:

—with tin, &c.

Silver

SILVER.

Native silver
and its ores.

Silver is found either native or mineralized. The native silver is found in Peru, and various parts of Europe; sometimes in considerable masses, and often diffused through sand, ochre, or lime-stone. It is seldom pure, but is generally alloyed with copper, and sometimes with gold, iron, or regulus of antimony. The mineralized silver contains sulphur and arsenic, or both, with other admixtures.

Purifying of
native silver.

Native silver may be purified by pounding or washing, or amalgamation with mercury; and the silver itself is refined by cupellation with lead in the same manner as gold. In the large way, the litharge, or vitrified lead, is blown from the surface of the silver by bellows, instead of soaking into the crucible. Gold may be separated from silver by parting with aqua regia, or treatment with sulphur in the dry way, which combines with the silver, and leaves the gold disengaged.

Vitreous ore
of silver.

The vitreous silver ore is the richest ore of silver, and contains from seventy to eighty pounds of silver in the hundred weight; the rest being sulphur, with rarely any other metal, except a small portion of iron. It is found either in solid large lumps, or inherent in quartz or spar. Its colour generally resembles that of lead; but grows dark by exposure to the air. It usually possesses a slight degree of malleability, and is sufficiently soft to be cut by a knife.

Analysis in the
moist way :

To analyse this ore in the moist way, it may be boiled in nitrous acid, which acidifies the sulphur, and causes great part to fly off in the form of vitriolic acid air. Common salt, or marine acid, will precipitate

pitate the silver in the form of luna cornea, which may be either reduced or accounted for by deducting one fourth of its weight when washed and dried, which fourth of its weight is marine acid.

SILVER.

In the dry way, it may be reduced by exposing it to a heat not sufficient to melt it. In this way the sulphur is dissipated, and the silver remains usually in a fibrous form. Small portions may be conveniently decomposed in this manner by the blow-pipe upon charcoal.

—in the dry way.

The red silver ore is a heavy shining substance, either transparent or opaque; sometimes grey or blackish, but always reddish when powdered: it usually contains more than half, and sometimes three fourths of its weight of silver, the rest being arsenic and sulphur.

Red silver ore.

In the moist way, this ore is analysed by reducing it to fine powder, and boiling it with diluted nitrous acid. The residue, which contains the sulphur and the arsenic, must beedulcorated with water; and the arsenic may be dissolved by boiling in a sufficient quantity of aqua regia. If the sulphur should retain any luna cornea, it may be separated by keeping it for some days in a closed vessel, with its own weight of diluted caustic volatile alkali. The clear nitrous solution being mixed with the water used in the edulcoration, affords a precipitate of luna cornea by the addition of sea salt, which may either be reduced or accounted for in the same manner as in the assay of the vitreous silver ore.

Analysis in the moist way.

Silver united with sulphur, arsenic, and copper, is generally called the white ore of silver. One hundred grains of this being reduced to a powder, and gently boiled

White ore of silver analysed.

SILVER.

boiled for an hour in more than twelve times its weight of diluted nitrous acid, the copper and silver are dissolved, and a white residuum remains. The silver is precipitated in the metallic form by the immersion of a clean plate of copper; and the copper being afterwards precipitated by the addition of volatile alkali, may be accounted for by allowing 194 grains of the precipitate to one hundred of the copper, and deducting the loss sustained by the plate of copper which was immersed in the solution. The white residuum may be deprived of its arsenic and iron by boiling in marine acid. The arsenic may be precipitated by the addition of water; and afterwards the iron, if any, by Prussian alkali. The undissolved sulphur may be treated with volatile alkali, to try whether it contains either copper or luna cornea.

The other ores of silver, of which there is considerable variety, may be analysed by varying the processes according to the supposed or known general contents of the ore*.

Method of assaying silver, or its ores, in the dry way.

See page 237.

Sulphureous and arsenical silver ores may be assayed by roasting and subsequent fusion with a greater or less quantity of flux. In the fusion, the silver is obtained alloyed with lead, copper, or iron, which may be separated by cupellation with lead, and the silver left pure. The fineness of silver is denoted by the assayers, by mentioning the number of pennyweights and grains of pure silver contained in the ounce. So

* For which consult Bergman's Treatise on the Art of Assaying in the Humid Way, inserted in the 2d vol. of the English translation of his Opuscula, or Essays.

that if an ounce of silver be found to lose half a pennyweight by cupellation, it is said to be eleven pennyweights twelve grains fine; if it lose a whole pennyweight, it is said to be eleven pennyweights fine,

SILVER.

&c. Silver is likewise tried by the touch, in the same manner as gold. For this purpose, the assayers are provided with a set of needles or small bars; the first of which contains $\frac{1}{16}$ part of its weight of copper, and the rest silver; the second contains $\frac{2}{16}$ parts of copper; the third $\frac{3}{16}$ parts; and so on to the last, which contains 15 parts of copper to one of silver. By the resemblance of colour on the touchstone, an estimate may be made of the fineness of the silver to something nearer than the 30th part of the whole, which is a considerable acquisition in the examination of small articles, such as rings, trinkets, and the like. It is true indeed that the use of the touch supposes the precious metal to be alloyed with copper only, which may not be the case; and consequently the assayer is liable to be deceived in this respect: but he may in this case have recourse to aqua fortis, or the blow-pipe, in the same manner as directed in the foregoing chapter.

Page 239, 240.
Assay of silver
by the touch.

In the large works, where silver is extracted, the processes are grounded on the properties already described. Native silver is triturated with mercury; after which the amalgam is washed, to separate the earthy particles; and the quicksilver separated, partly by pressure in leathern bags, and partly by distillation in iron retorts.

Extraction of
silver from
ores in the
large way, by
amalgamation:

Rich sulphureous ores are roasted, and fused with —by fire.
lead, to refine the silver by cupellation. The poorer

ores,

SILVER.

ores, which contain copper, are fused with pyrites, which affords a mass consisting of copper, sulphur, and silver. Lead is then added, and the mass treated in the way of eliquation. The lead flows out, carrying the silver with it; and, lastly, these two metals are separated by the test, on which the lead is converted into litharge, and the silver remains pure.

Uses of silver. The uses of silver are well known: it is chiefly applied to the forming of various utensils for domestic use, and as the medium of exchange in money. Its disposition to assume a black colour by tarnishing, and its softness, appear to be the chief objection to its use in the construction of graduated instruments for astronomical and other purposes, in which a good white metal would be a desirable acquisition.

CHAP. III.

CONCERNING PLATINA.

PLATINA is one of the metals for the discovery of PLATINA.
 which we are indebted to our cotemporaries. It Characters of
 has yet been found only in Spanish America, among platina.
 the gold mines there. We receive it in the form of
 small particles, from the minutest size up to that of a
 pea; though these last are very seldom met with. Its
 particles or grains are smooth, irregularly figured with
 round edges, and are flattened, probably by hammering
 in the mills in which the gold is amalgamated. These Crude platina.
 grains are of a whiter colour than iron, and are con-
 siderably malleable. In the state in which we receive
 them, they are often mixed with ferruginous sand,
 which may be separated by the magnet; and also with
 grains of quartz or crystal. When it is separated from
 heterogeneous particles, the crude platina itself is
 slightly magnetic, and is between sixteen and eighteen
 times as heavy as water. The most violent fires are
 insufficient to melt it, though its parts may be made to
 cohere together into a solid button by the strong heat
 of a wind furnace. Burning lenses of the most power-
 ful kind fuse it, and convert it into a malleable metal;
 and small portions of crude platina may be easily melted
 upon charcoal, by flame urged by a stream of vital
 air.

Pure or refined platina is by much the heaviest Pure platina.
 body in nature. It is very malleable, though confi-
 S derably

PLATINA.
 Characters of
 platina.

Welding.

Solution in de-
 phlogisticated
 marine acid :

—in aqua re-
 gia.

Distinctive
 character.

derably harder than either gold or silver ; and it hardens much under the hammer. Its colour on the touchstone is not distinguishable from that of silver. When in the highest degree of purity, it is not magnetic ; but when its specific gravity is as low as 21.36 it contains iron sufficient to render it magnetic. Pure platina requires a very strong heat to melt it ; but when urged by a white heat, it is said that its parts will adhere together by hammering. This property, which in iron is distinguished by the name of welding, is peculiar only to platina and that metal, which resemble each other likewise in their infusibility.

Platina is not altered by exposure to air ; neither is it acted upon by the most concentrated simple acids, even when boiling, or distilled from it. The dephlogisticated or aerated marine acid dissolves it, as does likewise aqua regia ; and both are said to form the same salts with it. In this particular of solubility platina resembles gold.

The aqua regia best adapted to the solution of platina is composed of equal parts of the nitrous and marine acids. The solution does not take place with rapidity. A small quantity of nitrous air is disengaged ; the colour of the fluid becoming first yellow, and afterwards of a deep reddish brown, which, upon dilution with water, is found to be an intense yellow. This solution is very corrosive, and tinges animal matters of a blackish brown colour : it affords crystals by evaporation. The metal is precipitable from its solution by sal ammoniac ; a property by which it is distinguished from all other metals, in the same manner

manner as the solution of gold is characterized by its precipitation upon the addition of martial vitriol. In this way, a compound solution of gold and platina may be separated by precipitating either of the two metals at pleasure. The orange-coloured precipitate of platina, obtained by means of sal ammoniac, is a saline substance, completely soluble in water; but its component parts have not been well ascertained. It is fusible without addition by a good forge furnace, and forms a brilliant, dense, and close-grained button, which is not malleable, probably on account of part of the saline substance not being dissipated.

PLATINA.

Separation of gold from platina.

The same precipitate, exposed to the stronger heat of a blast furnace, was fused into a perfectly malleable regulus by the Count de Milly. See Magellan's Cronstedt, page 574.—I have several small specimens of this platina, which is in thin plates or bars; their specific gravity is above $21\frac{1}{2}$; in which I do not pretend to a greater accuracy than $\frac{1}{1000}$ th part of the weight, because the quantities are so small. It is perfectly malleable, hard, and elastic, and obeys a strong magnet when the pieces are floated upon water. One small piece which was fused by Parker's lens is not at all magnetical, and seems to exceed 22 in specific gravity.

Malleable platina.

Alkalis and the soluble earths precipitate platina in the form of a calx from its solution. The Prussian alkali, hereafter to be described, does not precipitate it as it does all other metals; but it throws down a plentiful blue precipitate, consisting of iron, which was contained in the Prussian blue. This property therefore affords a method of separating the iron from

Precipitates.

PLATINA. from platina, which always contains it. The volatile alkali precipitates platina of an orange yellow colour. Neutral salts, with base of fixed alkali, do not precipitate it.

Most of the metals precipitate platina from its solution ; but it does not in general fall down in the metallic state.

Crucibles of platina.

This metal is scarcely affected in the dry way by saline substances. Calx of arsenic facilitates its fusion, and the semi-metal forms a brittle compound with the platina. Mr. Achard succeeded in making crucibles of platina, by fusing equal parts of platina, white arsenic, and vegetable alkali. This matter, when cooled, was reduced to a powder, and rammed into the mould of the vessel intended to be formed. A strong heat, quickly raised, and continued for some time, fused the mass ; and, after dissipating the arsenic and the alkali, left the platina in the form desired.

Combinations with metals.

Platina does not readily combine with gold, except by a strong heat ; and it greatly debases the colour of that metal : it does not readily unite with silver ; to which however it communicates part of its hardness, while it impairs its colour and brilliancy. It altogether resists the action of mercury ; or at least this mutual action does not seem to be stronger than that of mercury and iron. Lead and platina unite very well by fusion ; the lead becomes much less ductile, and even brittle, according to the proportions of the platina. In the attempts to cupel platina with lead, the process went on as it does usually with silver and gold in the beginning ; but as soon as a considerable portion of the lead was dissipated, the platina fixed, and the operation ceased.

Cupellation.

ceased. But with a stronger heat, such as that of a ^{PLATINA.} porcelain furnace, the operation may be completed, ^{Combinations} and malleable platina obtained free from lead. It has ^{with metals.} not been united with forged iron; but with cast iron it formed a brittle compound. With copper it melts with considerable facility; and in due proportions forms a compound which takes a very beautiful polish, and is not subject to tarnish: this has been used for the mirrors of reflecting telescopes. Tin and platina melt very easily, and form a compound, scarcely ductile when the tin abounds, but very brittle when the platina predominates. Bismuth and antimony unite with platina by fusion, and form brittle compounds, which do not promise to be of any considerable utility. Zinc likewise combines readily with it, and renders it very fusible; this alloy is brittle, hard, and of a blueish colour. Wolfram can scarcely be brought to shew any sign of union with platina. Cobalt, manganese, and molybdena have not been tried.

The commerce of platina has been interdicted by the Spanish ministry, from an apprehension that it might be employed in the adulteration of gold.—Whether this prohibition has since been taken off, I know not; but it seems needless, as the mixture of platina greatly alters the obvious qualities of gold, and can be very readily ascertained by the test of sal ammoniac before pointed out.

CHAP. IV.

CONCERNING MERCURY.

MERCURY.
 Characters of
 mercury.

MERCURY is distinguished from all other metals by its extreme fusibility, which is such that it does not take the solid state until cooled to the thirty-ninth degree below 0 on Fahrenheit's thermometer; and of course it is always fluid in the temperate climates of the earth. Its colour is white, and rather bluer than silver. In the solid state it is malleable*; its specific gravity is greater than that of any of the other metals, platina, gold, and wolfram excepted. It is volatile, and rises in small portions at the common temperature of the atmosphere, as is evinced by several experiments, more especially in a vacuum, such as obtains in the upper part of a barometer tube. At the temperature of about six hundred degrees it boils rapidly, and rises copiously in fumes. Few of the other metals melt at so low a temperature as the boiling point of mercury. When exposed to such a heat as may cause it to rise quickly in the vaporous form, it gradually becomes converted into a red calx, provided vital air be present. This is known by the name of precipitate per se. A greater heat however revives this metallic calx, at the same time that the vital air is again extricated.

* The reader will find an ample account of the freezing of quicksilver in Dr. Blagden's History, vol. lxxiii. of the Philosophical Transactions.

Mercury is not perceptibly altered by exposure to the air; though by long agitation, with access of air, it becomes converted into a black powder or calx, which gives out vital air by heat, the metal being at the same time revived. This metal is disposed to attract moisture; and cannot, for that reason, be used in the construction of the best barometers and thermometers until it has been first boiled in an open vessel for the space of about half an hour.

MERCURY.
Characters.

When mercury is agitated in a dry glass bottle, the Electric light. friction between the metal and the glass produces electricity. If the bottle be imperfectly exhausted, this electricity passes into the vacuum, and produces a light which was formerly thought to be a proof of the perfection of the vacuum in the upper part of barometer tubes; but which in fact does not appear in such barometers as have been cleared of air by careful boiling in the tube.

The vitriolic acid does not act on this metal, unless it be well concentrated and boiling. For this purpose, mercury is poured into a glass retort, with near twice its weight of vitriolic acid. As soon as the mixture is heated, a strong effervescence takes place, vitriolic acid air escapes, the surface of the mercury becomes white, and a white powder is produced; when the vitriolic air ceases to come over, the mercury is found to be converted into a white, opaque, caustic, saline mass, at the bottom of the retort, which weighs one third more than the mercury, and is decomposed by heat. Its fixity is considerably greater than that of mercury itself. If the heat be raised, it gives out a considerable

Action of vitri-
olic acid on
mercury.

MERCURY. quantity of vital air, the mercury being at the same time revived.

Vitriol and calx
of mercury.

The white mass produced by the action of vitriolic acid upon mercury, consists partly of a saline mass, or vitriol of mercury, and partly of a calx, or mercury united to vital air (simply, according to the new theory; or deprived of phlogiston, according to the old theory, which phlogiston is supposed to enter into the combination of the vitriolic acid air). Water separates the salt from the calx, which last is then of a yellow colour. Much washing is required to produce this colour, if cold water be used; but if a large quantity of hot water be poured on, the calx immediately assumes a bright lemon colour. In this state, it is called turbith mineral.

Turbith mine-
ral.

Precipitates.

The vitriol of mercury affords a salt by evaporation, in small needle-formed deliquescent crystals. The addition of a large quantity of water, more especially if heated, decomposes vitriol of mercury, which deposits turbith mineral, unless there be an excess of acid in the fluid.

Solution in ni-
trous acid.

The fixed alkalis, magnesia, and lime, precipitate mercury from its solution: these precipitates are reducible in closed vessels by mere heat without addition.

The nitrous acid rapidly attacks and dissolves mercury, at the same time that a large quantity of nitrous air is disengaged; and the colour of the acid becomes green during its escape. Strong nitrous acid takes up its own weight of mercury in the cold; and this solution will bear to be diluted with water. But if the solution be made with the assistance of heat, a much larger

larger quantity is dissolved; and a precipitate of calx ^{MERCURY.} will be afforded by the addition of distilled water, which is of a yellow colour if the water be hot, or white if it be cold, and greatly resembles the turbith mineral produced with vitriolic acid: it has accordingly been called nitrous turbith. ^{Nitrous turbith.} If acid be added to the solution made with heat, it loses its property of being decomposed by water. This decomposition is not complete, but only deprives the acid of the redundant calx.

All the combinations of mercury and nitrous acid ^{Mercurial nitre.} are very caustic, and form a deep purple or black spot upon the skin. They afford crystals, which differ according to the state of the solution. When nitrous acid has taken up as much mercury as it can dissolve by heat, it usually assumes the form of a white saline mass. When the combination of nitrous acid and mercury is exposed to a gradual and long continued low heat, it gives out a portion of nitrous acid, and becomes converted into a red substance, similar in all respects to the red calx of mercury formed by simply heating it in contact with vital air. ^{Red precipitate:} This is known by the name of red precipitate.

When red precipitate is strongly heated, a large ^{—decomposed.} quantity of vital air is disengaged, together with some phlogisticated air, and the mercury is sublimed in the metallic form.

Mercurial nitre is more soluble in hot than cold water, and affords crystals by cooling. It is decomposed by the affusion of a large quantity of water, unless the acid be in excess.

When mercury is dissolved in nitrous acid by means of

MERCURY. of heat, nitrous air is emitted at first; and afterwards it ceases, though the solution still proceeds. The mercury which is taken up during the first part of the process is calcined, and the other portion is dissolved in the metallic state. If the solution be stopped in the first part of the process, fixed and volatile pure alkalis precipitate the yellow calx; but if the solution be continued after the escape of the elastic fluid has ceased, the precipitate obtained by the same means is black, on account of the admixture of metallic mercury, which may be separated from the yellow calx by distillation.

Precipitates. Ponderous earth, magnesia, and lime, precipitate the nitrous solutions of mercury; and these precipitates, as well as all the other calces of this metal, are reducible by heat alone without addition.

Explosion of mercurial precipitates. The precipitates of mercury from acids, by means of alkalis, possess the property of exploding when exposed to a gradual heat in an iron spoon, after having been previously triturated with $\frac{1}{2}$ of their weight of flowers of sulphur. The residue consists of a violet-coloured powder, which is converted by sublimation into cinnabar. It seems therefore as if the sulphur combined suddenly with the mercury, and expelled vital air in the elastic state.

Decomposition of the nitrous solution by other acids. The vitriolic acid, or the salts containing it, decompose the nitrous solutions of mercury by virtue of the stronger attraction of the vitriolic acid to the metal. The precipitate which falls down does not essentially differ from the substance produced by the direct solution of mercury in the vitriolic acid. The marine acid likewise seizes the mercury dissolved in the nitrous acid,

and

and forms a compound which falls to the bottom. This **MERCURY.** consists of a very caustic salt, which is called corrosive **Corrosive sub-** sublimate, and is produced when the nitrous solution **limate.** contains only calx of mercury; but when that solution is saturated with metallic mercury, the compound which falls down by the addition of marine acid is called white precipitate, and does not differ from the preparation which, when made in the dry way, is called **Calomel.** calomel, or mercurius dulcis.

The acetous and most other acids combine with the calx of mercury, and precipitate it from its solution in the nitrous acid.

The marine acid does not act perceptibly upon mercury in the metallic state; but the dephlogisticated or **Combination of** aërated marine acid readily dissolves it, and forms the **mercury with** same combination as arises from the direct union of **dephlogisticat-** marine acid with calx of mercury; that is to say, corrosive sublimate. **ed marine acid.**

The great specific gravity of mercury rendered it an **Preparation of** object of peculiar attention to the alchemists and earlier chemists; many of whom hoped to fix it in the **corrosive sub-** form of a solid substance, or to extract gold from it. **limate.** From these motives, a great variety of processes have been made with it, by methods which are much less direct and simple than those of modern chemistry. Among others, the combination of the calx of mercury with marine acid is produced by several methods in the dry way by sublimation. In the large way, corrosive sublimate is prepared by triturating equal parts of mercury, common salt, and vitriol together, and exposing the whole to a moderate heat. The corrosive sublimate rises, and adheres to the upper part of the glass vessel.

MERCURY.
 Corrosive sub-
 limate.

vessel. In this operation, the vitriolic acid from the vitriol is supposed to calcine the mercury, or to dephlogisticate the marine acid of the common salt; in either of which cases the compound of marine acid with calx of mercury will be formed. From this theory, it will easily be understood that corrosive sublimate may be prepared by various methods. If the white mass or calx of mercury, produced by exposing that metal to the action of vitriolic acid, be heated in a matrass with an equal quantity of common salt, this sublimate will be had by double affinity; the vitriolic acid partly saturating the alkali, and the marine acid uniting with the calx of mercury, and rising by sublimation. In the same manner, the nitrous mercurial salt, or the mercurial precipitates, may be used instead of the calx of mercury by vitriolic acid.

Causiticity of
 metallic salts.

As the causiticity of metallic salts depends chiefly on the disposition of the calcined metal to resume the metallic state, at the same time that it burns or calcines the substance to which it may be applied; it is accordingly found that corrosive sublimate possesses this property in the most eminent degree; it is therefore one of the most active mineral poisons. This salt is soluble in water, though sparingly, and also in ardent spirit. It is precipitated of an orange colour by fixed alkalis. The absorbent earths likewise throw down its calx. Volatile alkali affords a white precipitate, which soon after assumes a slate colour.

Sal alembroth.

Corrosive sublimate becomes much more soluble in water by the addition of sal ammoniac, with which it forms a triple compound, called sal alembroth by the alchemists, which crystallizes by cooling. The addition

addition of a fixed alkali throws down a white calx of mercury, called white precipitate in the dispensaries. MERCURY.
White precipitate.

The preparation of calomel is usually made by triturating corrosive sublimate in a glass mortar with fluid mercury, added by a little at a time, until no more can be made to disappear. A small quantity of water added to the corrosive sublimate during this part of the process, prevents that salt from rising in the form of noxious dust. In this state, the combination is the same as that obtained from the saturated nitrous solution of mercury by the addition of marine acid. The mixture of corrosive sublimate and mercury is more perfectly combined by exposing it to sublimation. It adheres to the internal part of the subliming vessel in the form of a white mass, of a striated texture. If there be any suspicion of its containing corrosive sublimate, which is not probable on account of the more volatile nature of the latter, they may be separated by means of warm water, the calomel being insoluble.

When one part of antimony, which is the native combination or ore of antimony with sulphur, is triturated or accurately mixed with two parts of corrosive sublimate, and exposed to distillation, the dephlogisticated or aerated marine acid combines with the regulus of antimony, and rises in the form of the compound called butter of antimony; while the sulphur combines with the mercury, and forms cinnabar. If the regulus of antimony be used instead of the mineral, the residue which rises last consists of running mercury, instead of cinnabar. Butter of antimony.

The

MERCURY.

Cinnabar.

The combination of mercury and sulphur is called cinnabar. It is one of the most usual ores of this metal. Native cinnabar is not much used; but the artificial combination of the same nature is well known in the arts by the name of vermilion. The manufacture of this pigment has long been in the hands of the Hollanders, who kept it a secret; and as there is some difficulty in perfectly succeeding in the process, chemical writers have given various methods of performing it, most of which, according to Mr. Tuckert, are inaccurate. This gentleman has given a full account of the method used at Amsterdam, which I find extracted from Crell's Chemical Journal, and inserted in the fourth volume of the *Annales de Chimie*. Its contents are as follow:

The manufactory at which Mr. Tuckert several times assisted in the preparation of artificial cinnabar is without the Utrecht port at Amsterdam; and is one of the most considerable in Holland. Forty-eight thousand pounds of vermilion are annually made in three furnaces, by four workmen, besides other mercurial preparations.

The ethiops mineral is first prepared by mixing together 150 pounds of sulphur with 1080 pounds of pure mercury, and then exposing the mixture to a moderate heat in a flat-bottomed polished iron vessel, one foot in depth, and two feet and a half in diameter. Its form is that of a chocolate machine. Mr. Tuckert does not enter into the particular manipulations of the Hollanders in this part of the process, because the methods of producing the black combination of mercury with sulphur are well known.

The mercurial ethiops thus prepared is in the next place pounded, in order that it may more readily be put into small earthen bottles, capable of holding each about 24 ounces of water. Thirty or forty of these bottles are filled, to be in readiness for the subsequent operation.

MERCURY.

Cinnabar.

In the next place, three large pots or sublimatory vessels made of clay and very pure sand are taken. These vessels are previously covered with a coating of lute, which is suffered to become perfectly solid and dry before the vessel is used. Mr. Tuckert refers to a German translation of a work of Mr. Machy for the figure of these vessels, as well as for the composition of the lute. As we have not that translation, it is impossible for us to give any further information on these heads than may be gathered from the rest of this memoir. These pots are placed over three furnaces upon iron circles. The sublimatory vessels may be of different sizes, and the furnaces are constructed in such a manner as that the flame circulates freely round the vessels, to two thirds of their height.

When the vessels are duly placed in their furnaces, a moderate fire is first lighted, which is gradually raised until they become red hot. The fuel is turf, or rather peat, commonly used throughout the United Provinces. As soon as the vessels are red hot, a bottle of the ethiops is poured into the first, another into the second, and another into the third. In the subsequent progress of the operation, two, three, and perhaps more bottles may be poured in at a time; but this depends on the strength of the inflammation

MERCURY.

Cinnabar.

flammation exhibited by the ethiops after its introduction; the flame of which sometimes rises to the height of four and even six feet. When this is a little diminished, the mouth of the vessel is covered with a plate of iron, one foot square and an inch and a half thick, which perfectly closes it. In this way, during thirty-four hours, the whole of the prepared matter is introduced into the three pots, that is to say, for each pot three hundred and sixty pounds of mercury, and fifty of sulphur.

After all the ethiops has been introduced, the fire is duly kept up; and when the whole sublimation has taken place, it is suffered to go out, which requires thirty-six hours from first to last. The workmen know when the fire is too strong or too weak, by the appearance of the flame when the iron cover is taken off: if too strong, the flame rises to the height of several feet; if on the contrary it be too weak, the flame barely appears—playing about the edges of the pot. The proper degree of heat is, when upon taking off the cover a brisk flame appears, but does not rise more than three or four inches above the opening.

In the last thirty-six hours, the mass was stirred every quarter or half hour with an iron bar, to accelerate the sublimation. The workmen do this with so much courage, that Mr. Tuckert was every time apprehensive they would fall into the vessels.

When the whole is cool, the vessels are taken out by means of iron circles, which prevent their breaking. The cinnabar is taken out by breaking the
vessel.

vessel. Each vessel constantly affords four hundred pounds of cinnabar, the loss of original weight in each being ten pounds.

MERCURY.

Cinnabar.

The cinnabar does not attach itself to the plates of iron, because they are so frequently taken off, excepting towards the end, when the vessels were left untouched. These plates are not in the least corroded.

Livers of sulphur are decomposed in the humid way by mercury, which unites with the sulphur. With the fixed alkaline livers of sulphur it forms a black powder, or ethiops, by agitation, which in the course of a number of years becomes red; but the volatile alkaline hepar, or fuming liquor of Boyle, converts mercury into a fine cinnabar in a very short time. Turbith mineral, and the precipitates of mercury, are likewise converted into cinnabar by this alkaline hepar.

Cinnabar formed in the humid way.

Mercury unites by trituration with oils and mucilages, with which it forms black or deep blue compounds. A small part of the mercury in these seems to be in combination, and the rest in a state of extreme division.

Unguent, &c.

This metal can scarcely be exhibited in the dry way, on account of its volatility. The degree of heat required to convert it into the red calx called precipitate per se, is rather lower than its boiling point, and a greater reduces it again to the metallic state. The calcination and reduction of mercury, without addition, afford one of the strongest arguments in favour of the system which rejects phlogiston.

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In the production of the red calx of mercury, it is required that air be present, and the metal kept in a

Red calx of mercury, or precipitate per se.

T

state

MERCURY. state of brisk evaporation. On this account it is found convenient that the vessel should be so deep, and its aperture so small, that the fumes may not make their escape. It may be inferred that, in this as well as other calcinations, there is an absorption of vital air; more especially as vital air is expelled from the calx by heat *. When the experiment is made in closed vessels by means of a body of the kind marked C, fig. 15, whose neck is introduced beneath a jar containing common air over mercury, the vital part is absorbed, and phlogisticated or foul air remains; and afterwards, by an augmentation of heat, the mercury is revived, at the same time that it restores the constitution of the air by the emission of the vital air. Ten days or a fortnight's constant heat is required to convert a few grains of mercury into precipitate per se in the small way.

Amalgams.

Mercury, being habitually fluid, very readily combines with most of the metals, to which it communicates more or less of its fusibility. When these metallic mixtures contain a sufficient quantity of mercury to render them soft at a mean temperature, they are called amalgams.

Combinations of metals.

It very readily combines with gold, silver, lead, tin, bismuth, and zinc; more difficultly with copper, arsenic, and regulus of antimony; and scarcely at all with platina or iron: it does not unite with nickel or cobalt; and its action on manganese, wolfram, and molybdena is not known. Looking-glasses are covered on the back surface with an amalgam of tin.

* Lavoisier, *Traité Élémentaire de Chimie*, page 35.

In this operation, mercury is poured on tin foil, upon a flat stone, and spread with a feather till its union with the tin has brightened every part of its surface. A large quantity of mercury is then poured on, and the glass is slid along the fluid surface; upon which it is afterwards pressed by weights, to exclude the superfluous mercury.

MERCURY.

Combinations
of metals.

Mercury is found native in slaty or quartzose earths, or visibly diffused through masses of clay or stone. Native mercury and its ores. Native precipitate per se, or calx of mercury, has also been found; and this metal has likewise been met with in combination with the vitriolic and marine acids. Its volatility may probably have caused it to be overlooked in many minerals that may contain it. The greatest quantity of mercury is found in combination with sulphur, in the form of cinnabar. Mercury is a scarce metal: Most of the mercury in commerce is afforded by the mines of Idria in the Austrian dominions, Almaden in Spain, and Guancavelica in Peru. The native mercury requires little more than washing to separate it from its matrix. Cinnabar in the native state is frequently mixed with calcareous earth; in which case the mercury may be separated by distillation, because the calcareous earth combines with and detains the sulphur. Pure cinnabar may be decomposed by the addition of about one third of its weight of iron. In all cases wherein pure mercury is required, it must be distilled from cinnabar, or its sulphureous combination. For this purpose, the mercury may be converted into ethiops, and distilled with twice its weight of quicklime or iron filings. Mercury in commerce is judged to be pure, when it is perfectly

Decomposition
of cinnabar.Purity of mer-
cury.

MERCURY.

fluid, and runs in neat globules, without any pellicle on its surface, or without soiling a funnel of clean white paper, through which it may be poured by a very small aperture at bottom. If it leaves nothing behind after evaporation, its purity may be still more depended upon.

Humid analysis of cinnabar.

To analyse native cinnabar, its stony matrix should first be dissolved in nitrous acid; and the cinnabar, being disengaged, should be boiled in eight or ten times its weight of aqua regia, composed of three parts nitrous, and one marine acid: the mercury may then be precipitated in the metallic form by the addition of zinc.

Uses of mercury.

The uses of mercury have already been mentioned in the present chapter, and elsewhere. The amalgamation of the noble metals, water-gilding, the making of vermilion, the silvering of looking-glasses, and the preparation of several powerful medicines, are the principal uses to which this metal is applied.

C H A P. V.

CONCERNING LEAD.

L EAD is a white metal, of a considerably blue tinge, very soft and flexible, not very tenacious, and consequently incapable of being drawn into fine wire, though it is easily extended into thin plates under the hammer. Its weight is very considerable, being rather greater than that of silver. Long before ignition, namely, at about the 540th degree of Fahrenheit's thermometer, it melts; and then begins to be calcined, if respirable air be present. In a strong heat it boils, and emits fumes; during which time, if exposed to the air, its calcination proceeds with considerable rapidity. If melted lead be poured into a box previously rubbed with chalk to prevent its action on the wood, and be continually agitated, it will con-
LEAD.
Characters of
lead.
Granulated.

This metal, during the progress of heat, first be-
Calcination.
 comes converted into a dusky powder, which by a continuation of the heat becomes white, yellow, and afterwards of a bright red inclining to orange colour, called minium, or red lead. The process requires
Minium, or
red lead.
 considerable management with regard to the heat and

LEAD.

Litharge and
glass of lead.

Achromatic-te-
lescope.

Action of air
and water on
lead :

—of vitriolic
acid.

access of air, in the making of red lead. Many days are required for this purpose. If the heat be too great or rapid, the lead becomes converted into a flaky substance, called litharge; and a still greater heat converts it into a clear, transparent, yellow glass, which powerfully dissolves and corrodes metallic calces or earths; and on this account it usually finds its way through the crucibles in a short time. It acts more difficultly on argillaceous than on siliceous earths; whence it is found that vessels made of clay mixed with broken pottery are preferable to those that are composed of clay and sand. The calx of lead is a principal ingredient in most of the modern fine white glasses. It is more particularly calculated to form the dense glass used to correct the aberration arising from colour in those telescopes which are known by the name of achromatic; because it communicates the property of separating the coloured rays from each other in greater angles than obtain in alkaline glasses at equal angles of mean refraction. The imperfection which most considerably affects this kind of glass is, that its density is seldom uniform throughout. The irregularities shew themselves in the form of veins, which greatly disturb the regular refraction.

Lead is not much altered by exposure to air or water; though the brightness of its surface, when cut or scraped, very soon goes off. It is probable that a thin stratum of calx is formed on the surface, which defends the rest of the metal from corrosion.

Most of the acids attack lead. The vitriolic acid does not act upon it, unless it be concentrated and boiling. Vitriolic acid air escapes during its process.

cess, and the acid is decomposed. When the distillation is carried on to dryness, a saline white mass remains, a small portion of which is soluble in water, and is the vitriol of lead: it affords crystals. The residue of the white mass is a calx of lead.

LEAD.

Nitrous acid acts strongly on lead, and converts it into a white calx if the acid be concentrated; but if it be more diluted, the calx is dissolved, and forms a nitre of lead which is crystallizable, and does not afford a precipitate by cooling. It detonates on ignited coals. Lime and alkalis decompose the nitrous solution of lead. The vitriolic acid added to this solution combines with the metallic calx, and falls down. The marine acid in the same manner carries down the lead, and forms a combination called plumbum cerneum, which is more soluble in water than the horn silver.

Combination of nitrous acid and lead.

Plumbum cerneum:

Marine acid acts directly on lead by heat, which it calcines, and dissolves part of its calx. The marine salt of lead is crystallizable.

—marine acid,

The acetic acid dissolves lead and its calces; though probably the access of air may be necessary for the solution of the metal itself in this acid. White lead, or ceruse, is made by rolling leaden plates spirally up, so as to leave the space of about an inch between each coil, and placing them vertically in earthen pots, at the bottom of which is some good vinegar. The pots are to be covered, and exposed for a length of time to a gentle heat in a sand bath, or by bedding them in dung. The vapour of the vinegar, assisted by the tendency of the lead to combine with the pure part of the air which is present, corrodes the lead, and converts the

—acetic acid.

White lead, or ceruse.

LEAD.

external portion into a white calx, which comes off in flakes when the lead is uncoiled. The plates are thus treated repeatedly until they are corroded through. Ceruse is the only white substance used in oil paintings. It may be dissolved without difficulty in the acetous acid, and affords a crystallizable salt, called sugar of lead from its sweet taste. This, like all the preparations of lead, is a most deadly poison.

Action of liver
of sulphur on
lead :

—of alkalis :

Liver of sulphur precipitates lead from its solutions, the sulphur falling down in combination with the lead. Pure alkaline solutions dissolve a small portion of lead, and corrode a considerable quantity : the solution is said to give a black colour to the hair.

—oils.

Oils dissolve the calces of lead, and become thick and consistent ; in which state they are used as the basis of plasters, cements for water works, paint, &c.

Habitudes in
the dry way.

In the dry way, lead alone is calcined and vitrefied. When fused with fixed alkaline salts, it is converted into a dark-coloured scoria, partly soluble in water. The neutral salts in general are not acted upon by lead. Nitre calcines this metal when heated with it, though scarcely any commotion or apparent flame is produced by its action. Sulphur readily dissolves it in the dry way, and produces a brittle compound, of a deep grey colour and brilliant appearance, which is much less fusible than lead itself ; a property which is common to all the combinations of sulphur with the more fusible metals.

The

The phosphoric acid, exposed to heat together with charcoal and lead, becomes converted into phosphorus, which combines with the metal. This combination does not greatly differ from ordinary lead: it is malleable, and easily cut with a knife; but it loses its brilliancy more speedily than pure lead; and, when fused upon charcoal with the blow-pipe, the phosphorus burns, and leaves the lead behind.

LEAD.

Habitudes with
phosphoric
acid.

Lead decomposes sal ammoniac by the assistance of heat: its calces unite with the marine acid of that salt in the cold, and disengage its volatile alkali. When volatile alkali is obtained by distilling sal ammoniac with the calces of lead, the residue consists of plumbum corneum.

Decomposition
of sal ammo-
niac:

Litharge fused with common salt decomposes it; the lead unites with marine acid, and forms a yellow compound, at present used in this country as a pigment, for which an exclusive privilege has been granted. The alkali either floats at top, or is volatilized by the heat if strongly urged. The same decomposition takes place in the humid way, if common salt be macerated with litharge; and the solution will contain caustic alkali.

—of common
salt.

Page 122.

Lead unites with most of the metals. Gold and silver are dissolved by it in a slight red heat. Both these metals are said to be rendered brittle by a small admixture of lead, though lead itself is rendered more ductile by a small quantity of them. Platina forms a brittle compound with lead; mercury amalgamates with it; but the lead is separated from the mercury by agitation, in the form of an impalpable black powder,

Combinations
of lead with
metals.

LEAD. powder, vital air being at the same time absorbed.

Combinations
of lead and cop-
per; decompo-
sed by eliqua-
tion, or by low
heat.

The presence of vital air is indispensably necessary in this process. Copper and lead do not unite but with a strong heat. If lead be heated so as to boil and smoke, it soon dissolves pieces of copper thrown into it; the mixture when cold is brittle. The union of these two metals is remarkably slight; for upon exposing the mass to a heat no greater than that in which lead melts, the lead almost entirely runs off by itself.

This process, which is peculiar to lead with copper, is called eliquation. The coarser sorts of lead, which owe their brittleness and granulated texture to an admixture of copper, throw it up to the surface on being melted by a small heat. Iron does not unite with lead, as long as both substances retain their metallic form. Tin unites very easily with this metal, and forms a compound which is much more fusible than lead by itself, and is for that reason used as a solder for lead.

Plumbers sol-
der.

Two parts of lead and one of tin form an alloy more fusible than either metal alone; this is the solder of the plumbers. Bismuth combines readily with lead, and affords a metal of a fine close grain, but very brittle.

Fusible mix-
ture.

A mixture of eight parts bismuth, five lead, and three tin, will melt in a heat which is not sufficient to cause water to boil. Regulus of antimony forms a brittle alloy with lead. Wolfram unites with it into a spongy ductile compound, which splits into leaves when hammered. Nickel, cobalt, manganese, and zinc, do not unite with lead by fusion.

Revival of the
calces of lead.

All the calces of lead are very easily revived. Minium, when exposed to a strong heat, gives out part of

of the vital air it absorbed during its calcination ; but, like the other calces of this metal, it requires the addition of some combustible substance for its complete revival. A familiar instance of this revival is seen by exposing the common wafers to the flame of a candle. These wafers are coloured with minium, which is revived by the heat and inflammable substance of the wafer, so that it falls down in metallic globules.

LEAD.

Lead is found native, though seldom ; and also in the form of a calx, called native ceruse, or lead ochre, or lead spar of various colours, red, brown, yellow, green, blueish, and black. These ores, when freed as much as possible from earthy matter, may be dissolved in diluted nitrous acid. Calx of iron is usually thrown down from the solution by boiling. If the lead be then precipitated by the mild mineral alkali, and weighed, 132 grains of the dry precipitate will correspond with 100 grains of lead in the metallic state. If the precipitate be suspected to contain copper, it may be separated by digesting in volatile alkali. If it be supposed to contain silver and copper, the precipitate may again be dissolved in nitrous acid, and separated by the addition of marine acid ; which combining with the metal, produces luna cornea, and plumbum corneum ; the latter of which, being soluble in 30 times its weight of boiling water, may be washed off, while the silver remains undissolved ; or the silver, if alone in the precipitate, may be taken up by volatile alkali, which will leave the calx of lead of the same value with regard to weight

Native lead
and its ores.

Analysis of
calcareous ores.

LEAD. weight as the foregoing. Lead is also found mineralized by the vitriolic and the phosphoric acids: this last is of a greenish colour, arising from a mixture of iron. The vitriol of lead is soluble in about 18 times its weight of water. One hundred and forty-three grains of the dried salt represent 100 grains of lead. The phosphoric lead ore may be dissolved in nitrous acid by means of heat, except a few particles of iron, which remain at the bottom. By the addition of vitriolic acid the lead is thrown down in the form of white flakes of vitriol; which, when washed and dried, discover the quantity of lead they contain, by the same allowance of 143 grains of the salt to 100 grains of metallic lead. The remaining solution, being evaporated to dryness, affords phosphoric acid.

Native salts of lead.

Humid analysis of phosphoric lead ore.

Sulphureous ore of lead; or galena.

Lead is abundantly found in combination with sulphur, in the form of heavy, shining, black, or blueish lead-coloured cubical masses, whose corners are usually truncated; its texture is laminated, and its hardness variable. This is called galena, or potters lead ore. Most lead ores contain more or less of silver. When antimony enters into its composition, the texture is radiated or filamentous. There are also lead pyrites, which contain a considerable proportion of iron and sulphur; and red lead spar, which consists of lead mineralized by sulphur and arsenic: this is very scarce.

Analysis of sulphurated lead.

If sulphurated lead be boiled in nitrous or marine acid of a moderate strength, the sulphur may be obtained pure, and collected on a filter. When iron
or

or stony particles are contained among the undissolved part, the sulphur may be separated by digestion in a solution of caustic fixed alkali, which converts it into liver of sulphur, and leaves the other insoluble matters behind. If the first solution be made with nitrous acid, it may contain silver and lead, which, after precipitation by mild mineral alkali, may be separated by the volatile alkali, as mentioned in the humid analysis of the calciform ores : when the marine acid is used for the solution of the ore, a large quantity of plumbum corneum separates, for want of a sufficient quantity of water to dissolve it. This requisite quantity of water must be added to dissolve the salt before the precipitate is made by the fixed alkali.

LEAD.

All the ores of lead, except the phosphoric, are reducible to the metallic state by dissipating their volatile contents by the blow-pipe on a piece of charcoal. In the large way, they are revived by fusion with charcoal.

Revival of lead by the blow-pipe.

The ores of this metal are abundantly found in the mine counties of England, and in various other parts of the globe. Its uses are numerous, and scarcely need be mentioned. Its calces have been already mentioned as of great use as a pigment, and in the manufacture of glass. Lead is cast into thin sheets for covering buildings, making water-pipes, and various other uses ; and this is rolled between two cylinders of iron, to give it the requisite uniformity and thinness. Lead is thought, and with some reason, to be not perfectly innocent even for water-pipes, and much less so for any other kind of vessels. The work-

men

LEAD.

men in any of the preparations of lead are generally subject to a peculiar colic, and paralytic disorders; which most probably arise from the internal use of the metal: for it is a fact that these workmen are not sufficiently cautious in washing their hands, or removing such particles of lead, or its preparations, as may casually intermix with their food.

C H A P. VI.

CONCERNING COPPER.

COPPER is a metal of a peculiar reddish brown colour; hard, sonorous, very malleable, and ductile; of considerable tenacity, and of a moderate specific gravity. At a degree of heat far below ignition the surface of a piece of polished copper becomes covered with various ranges of prismatic colours, the red of each order being nearest the end which has been most heated; an effect which must doubtless be attributed to calcination, the stratum of calx being thickest where the heat is greatest, and growing gradually thinner and thinner towards the colder part. A greater degree of heat calcines it more rapidly, so that it contracts thin powdery scales on its surface, which may be easily rubbed off; the flame of the fuel becoming at the same time of a beautiful blueish green colour. In a strong white heat, nearly the same as is necessary to melt gold or silver, it melts, and exhibits a blueish green flame; by a violent heat it boils, and is volatilized partly in the metallic state.

COPPER.
 Characters of
 copper.

See Newton's
 Optics.

Copper rusts in the air; but the corroded part is very thin, and preserves the metal beneath from further corrosion.

Corrosion of
 copper:

The vitriolic acid, when concentrated and boiling, dissolves copper. A brown thick fluid, containing calx of copper, and a portion of the calx combined

—and solution
 in vitriolic acid.

COPPER.

with vitriolic acid, is found at the bottom of the solvent. If water be added to this, it forms a blue solution of copper, which by evaporation affords blue crystals, that require about four times their weight of water to dissolve them. This solution lets fall a calx of copper of a green colour by long exposure to the air.

Vitriolic combinations and precipitates.

The solutions of copper in vitriolic acid are slightly caustic. Magnesia, lime, and the fixed alkalis, precipitate the metal from them in the form of calx. Volatile alkali precipitates all the solutions of copper; but redissolves the calx, and produces a deep blue colour. Copper is precipitable from most of its solutions in the metallic state by the addition of iron: a clean plate of iron soon becomes covered with a coating of copper when immersed in the solution: hence the volatile alkali, and the application of iron, are considered as the tests of the presence of copper. There are certain mineral waters in Hungary, Sweden, Ireland, and in various parts of England, which contain vitriol of copper, and from which it is precipitated by the addition of pieces of old iron.

Nitrous combination of copper.

Nitrous acid dissolves copper with great rapidity, and disengages a large quantity of nitrous gas. Part of the metal falls down in the form of a calx; and the filtrated or decanted solution, which is of a much deeper blue colour than the vitriolic solution, affords crystals by slow evaporation. This salt is deliquescent, very soluble in water, but most plentifully when the fluid is heated. Its solution, exposed to the air in shallow vessels, deposits a calx of a green colour. Lime precipitates the metal of a pale blue; fixed alkalis, of a blue-

ish

ish white. Volatile alkali throws down blueish flocks, which are quickly redissolved, and produce a lively blue colour in the fluid. COPPER.

Marine acid does not readily dissolve copper, unless it be concentrated and boiling. The solution is of a deep brown colour; but, on standing for some time, it deposits a sediment, and becomes green. By careful evaporation it yields crystals; or, when inspissated, it affords a greenish mass, which deliquesces in the air, is readily dissolved in water, gives a green tincture to ardent spirit, melts in a gentle heat, takes fire from a candle, and burns with a blue flame. The marine acid dissolves the calces of copper more readily than the metal itself; but the solution does not differ from the foregoing.

Vegetable acids dissolve copper slowly; but in considerable quantity, if respirable air be present. In this, as in a number of other metallic solutions, it appears that the disposition of the air to calcine the metal is greatly assisted by the elective attraction of the acid for the metallic calx. Vinegar does not dissolve copper when boiling, because the steam prevents the access of the air; but the same acid standing for a day in a copper vessel, will contract a dangerous metallic impregnation. This circumstance accounts for the unhappy consequences in some instances attending the use of copper vessels, which in other cases have produced no noxious effects. Confectioners boil pickles, and even lemon juice, in clean copper vessels, without observing any bad taste or noxious consequence to follow. We cannot however avoid heartily concurring in the general

—in vegetable acids.

Effect of the presence of air.

COPPER.

Fabrication of
verdigris.

ral opinion which now prevails, in the rejection of copper vessels for culinary purposes.

Verdigris is a calx of copper prepared in large quantities near Montpellier in France, by stratifying copper plates with the husks of grapes which remain after the juice has been pressed out. These soon become acid, and corrode the copper. A solution of this calx in distilled vinegar affords permanent crystals, improperly called distilled verdigris.

Solution of cop-
per in fixed al-
kalis :

Fixed alkalis have some action on copper, with which they form a light blue solution. This, as well as the volatile alkaline solution, appears to succeed better in the cold than by the assistance of heat, for the same reason as the cold acetous acid acts upon copper; namely, the facility with which the metal is calcined by the access of air.

—in volatile
alkali.

Volatile alkali dissolves copper with much greater rapidity than fixed alkalis, whether it be in the metallic or calciform state; and forms a beautiful blue solution. This fluid has long attracted the notice of chemists, on account of its becoming colourless in closed vessels; and recovering its colour, which gradually extends from the surface downwards, when the vessel is opened. This effect is explained by the supposition, that the perfect solution of calx of copper in volatile alkali is colourless when the alkali is in excess; but that it is blue when it abounds with calx of copper: and accordingly it is found that the loss of colour on keeping the vessel closed for some time, and its re-appearance on opening the vessel, does not succeed with old solutions, which are permanently blue. The
air

air calcines more perfectly a portion of the suspended copper, which gives a blue colour to the fluid until it has more intimately combined with the alkali. If this combination be made in the closed vessel, the colour disappears; if it be made in the open vessel, the calcination of another portion goes on, and continues until the alkali is saturated, and can combine with no more: so that the last portion of perfect calx, which causes the blue colour, does not seem to have entered into so intimate a combination, for want of an excess of alkali. The alkali does not take up any considerable quantity when applied to copper filings; but it dissolves much more of the calces of copper. The solution does not very readily afford crystals.

COPPER.

Habitudes of
copper with
volatile alkali:

Oils do not seem to act upon copper until they become rancid; in which case their disengaged acid corrodes the copper, and the oil assumes a blueish green colour. Verdigris is soluble in ardent spirit. Copper in the metallic state does not unite with earths or alkalis in the dry way: its calces enter into the composition of glass. In general, it does not act on the neutral salts by fusion. Nitre detonates with it but difficultly. Filings of copper are thrown upon red-hot nitre; and the residue is a brownish grey calx, mixed, and partly combined, with vegetable alkali. If this be washed with water, the remaining calx may be fused, without other addition, into a deep opaque brown glass, used by enamellers.

—with oils,
earths, alkalis,
and neutral
salts:

Sal ammoniac is decomposed by copper filings. The produce which comes over consists of caustic

—sal ammo-
niac.

U 2

volatile

COPPER.
 Habitudes of
 copper with
 fal ammoniac :

volatile alkali, rendered blue by a small portion of copper, together with alkaline air, inflammable air, and phlogisticated air: the residue consists partly of marine salt of copper and calx. In this experiment we find that the copper detains the acid; while the volatile alkali, being set at liberty, comes over into the receiver. The inflammable and phlogisticated air cannot so clearly be accounted for, as they may arise either from part of the alkali being decomposed into its first principles; or the inflammable air may be supplied during the solution of the copper; in which case it will proceed from the phlogiston of that metal, according to the hypothesis of Stahl; or from a decomposition of part of the water of crystallization of the fal ammoniac; the pure air of which will be communicated to the copper, in order to calcine and render it soluble in the marine acid, while its inflammable air comes over in the elastic state.

—with alum :

A solution of alum boiled in a copper vessel deposits some earth; and the fluid exhibits signs of the presence of copper by the test of volatile alkali. This does not seem to be a perfect decomposition of the alum; but appears to be effected by virtue of the acid, which that salt contains in excess. The neutral salt or alum, saturated with its own basis, falls down, because less soluble; while the excess of acid, forming vitriol of copper, exhibits the blue tinge when volatile alkali is added.

—with sulphur.

Copper unites very readily with sulphur. If copper filings be mixed with flowers of sulphur and a little water, the combination takes place; but it is much more

more readily effected in the dry way. This cannot be done by direct fusion, because the sulphur is burned at a much less heat than is required to fuse the copper.

COPPER.

It may be prepared by mixing equal parts of sulphur and copper filings together, and exposing them to heat, gradually raised to ignition: or plates of copper may be stratified in a crucible with sulphur, and gradually heated as before. This compound is a blackish grey mass; and is used by dyers and callico-printers: it is distinguished by the name of *æs veneris*. Liver of sulphur dissolves copper both in the humid and dry way.

Combination
of copper with
sulphur +

Phosphorus unites with the calx of copper: or if the phosphoric glass be exposed to heat in a crucible, together with its weight of copper filings, and about $\frac{1}{4}$ of its weight of charcoal, the phosphorus which is formed combines with the copper into a kind of pyrites, which changes by exposure to air. It loses its metallic state, and assumes a black colour.

—with phos-
phorus:

The combinations of copper with the metals before treated of have been already mentioned. It unites imperfectly with iron in the way of fusion. Tin very readily combines with copper at a temperature much lower than is necessary to fuse copper alone. On this is grounded the method of tinning copper vessels. For this purpose, they are first scraped, or scoured; after which they are rubbed with sal ammoniac. They are then heated, and besprinkled with powdered resin, which defends the clean surface of the copper from acquiring the slight film of calx, which would prevent the adhesion of the tin to its surface. The melted tin is then poured in, and spread about.

—with metal-
lic substances.

COPPER.

An extremely small quantity adheres to the copper; which may with great justice be supposed insufficient to prevent the noxious effects of the copper as perfectly as might be wished.

Bronzes and
bell-metal.

When tin is melted with copper, it composes the compound called bronze. In this metal the specific gravity is always greater than would be deduced by computation from the quantities and specific gravities of its component parts. The uses of this hard, sonorous, and durable composition, in the fabrication of cannon, bells, statues, and other articles, are well known. Bronzes and bell-metals are not usually made of copper and tin only, but have other admixtures, consisting of lead, zinc, or arsenic, according to the motives of profit, or other inducements of the artist. But the attention of the philosopher is more particularly directed to the mixture of copper and tin, on account of its being the substance of which the speculums of reflecting telescopes are made. The metal required for this purpose ought to be capable of an exquisite polish, hard enough to receive and retain a figure accurately suited to the regular reflection of light, and not subject to become tarnished by the action of the atmosphere. Many excellent telescopes have been made with compositions of pure copper, alloyed with somewhat less than half its weight of tin. But it appears to be very well ascertained, from the observations of the Astronomer Royal, that the speculums of Mr. Edwards, whose composition was the result of numerous trials, are much superior to any which have yet been made; and are even equal in light to achromatic

Metal for speculums.

matic telescopes of the same aperture, without altering the colours of objects. He first melts 32 parts of copper as fluid as possible, with one part of brass and one of silver, together with the black flux; at the same time that fifteen parts of tin are melted in a separate crucible by itself. These being taken from the fire, he pours the tin to the copper; immediately stirs the whole together with a wooden spatula, and pours it out hastily into a large quantity of cold water, which cools and granulates the composition. If the tin were fused together with the copper, or if they were to remain for any length of time in the extreme heat which is necessary to fuse this last metal, a part of the tin would be calcined, and the metal would abound more or less with small microscopic pores. If one of the pieces of the cold metal be broken, it will appear of a most beautiful bright colour, resembling quicksilver. Mr. Edwards affirms, that different kinds of copper require different doses of tin to produce the most perfect whiteness. If the dose of tin be too small, which is the fault most easily remedied, the composition will be yellowish; if it be too great, the composition will be of a grey blue colour, and dull appearance. He therefore finds by trial the quantity of tin necessary to be added in the second fusion to render the metal the most perfect. A much less degree of heat is then required to melt the compound. In the second melting he adds one part of arsenic, and immediately stirs the mixture; which he pours into the mould as soon as the fumes of the arsenic have ceased to rise. He casts the speculum

COPPER.

Edwards's method of making speculums.

COPPER.
Metallic mix-
tures.

cullum in sand, with the face downwards; takes it out while red-hot, and places it in hot wood-ashes to cool; without which precaution it would break in cooling*.

Copper unites with bismuth, and forms a reddish white alloy. With arsenic it forms a white brittle compound, called tombac. With zinc it forms the compound called brass, and distinguished by various other names, according to the proportions of the two ingredients. It is not easy to unite these two metals in considerable proportions by fusion, because the zinc is burned or volatilized at a heat inferior to that which is required to melt copper; but they unite very well in the way of cementation. In the brass works, copper is granulated by pouring it through a plate of iron, perforated with small holes and luted with clay, into a quantity of water about four feet deep, and continually renewed. To prevent the dangerous explosions of this metal, it is necessary to pour but a small quantity at a time. There are various methods of combining this granulated copper, or other small pieces of copper, with the vapour of zinc. Calamine, which is an ore of zinc, is pounded, and

* As the construction of telescopes is foreign to the immediate purpose of this work, it has not been thought necessary to mention the several precautions of Mr. Edwards in this business: but the curious operator, who may wish to undertake the construction of a reflecting telescope (the better kinds of which are not only difficult to be procured, but of considerable price), may have recourse to Edwards's Treatise, annexed to the Nautical Almanack for 1787; where he will find ample instructions for that purpose.

mixed with the divided copper, together with a ^{COPPER.} portion of charcoal. These being exposed to the ^{The fabrication of brass.} heat of a wind furnace, the zinc becomes revived, rises in vapour, and combines with the copper, which it converts into brass. The heat must be continued for a greater or less number of hours, according to the thickness of the pieces of copper, and other circumstances; and at the end of the process the heat, being suddenly raised, causes the brass to melt, and occupy the lower part of the crucible. The most scientific method of making brass seems to be that mentioned by Cramer*. The powdered calamine, being mixed with an equal quantity of charcoal, and a portion of clay, is to be rammed into a melting vessel; and a quantity of copper, amounting to two thirds of the weight of the calamine, must be placed on the top, and covered with charcoal. By this management the volatile zinc ascends, and converts the copper into brass, which flows upon the rammed clay: consequently, if the calamine contain lead, or any other metal, it will not enter into the brass, the zinc alone being raised by the heat.

A fine kind of brass, which is supposed to be made ^{Leaf brass, or Dutch gold.} by cementation of copper plates with calamine, is hammered out into leaves in Germany; and is sold very cheap in this country under the name of Dutch gold. It is, as I find, about five times as thick as gold leaf; that is to say, it is about one sixty-thousandth of an inch thick.

* Art of Assaying Metals. London, 1764. Page 377.

COPPER.

Metallic mix-
tures.

If brass be kept in a state of ignition, with contact of air, the zinc burns, and the copper remains. Whether the zinc would quit the brass without combustion, is not known; though there is little doubt but it might be driven off in close vessels.

The quantity of zinc in good brass is about one third of its weight.

Copper unites readily with regulus of antimony; and affords a compound of a beautiful violet colour. It does not readily unite with manganese. With wolfram it forms a dark brown spongy alloy, which is somewhat ductile.

Native copper,
and its ores.

Copper is either found native, mostly in an impure state; or in the form of a calx, of a red, green, or blue colour. The native solutions of copper frequently impregnate calcareous earths, in which they deposit the metal. The turquoise stone is the tooth of an animal penetrated with the blue calx of copper. Many ores of copper contain sulphur. Among these, the vitreous copper ore is of a red, brown, blue, or violet colour; sometimes crystallized, but usually soft enough to be cut with a knife. Some of the pyrites contain a considerable proportion of copper, together with iron, sulphur, and clay. The grey copper ore is a sulphureous combination, containing arsenic: it is of a white, grey, or brown colour, heavy, and difficult of fusion. Blendose copper ore is of a brown colour, hard, solid, compact, and granulated: it contains the metal, with sulphur, arsenic, zinc, and iron. Some slates, and one species of coal, afford copper; and several waters contain

contain this metal, dissolved in vitriolic or marine acid.

COPPER.

Native copper may be assayed in the humid way by solution in nitrous acid. If it contain gold, this metal falls untouched to the bottom, in the form of a black powder; if silver, it is soon precipitated by more copper; if iron, by boiling the solution for some time, it is gradually calcined, and falls to the bottom.

Assay of native copper:

The calciform copper ores are soluble in acids, and may be precipitated either by iron, which affords the copper in the metallic state; or by mild alkali, which throws down 194 grains of precipitate for every 100 grains of copper.

—of calciform ores:

Sulphureous copper ores may be powdered, and gently boiled to dryness in five times their weight of concentrated vitriolic acid. The whole, or most part, of the sulphur flies off by this heat. The vitriolic salt of copper requires at least four times its weight of water to dissolve it. A sufficient quantity being therefore added, and a polished iron plate boiled in the solution, the copper will be precipitated. If iron be found to be mixed with the precipitate, it must be again dissolved, to obtain a richer solution. This will deposit pure copper, if the operation be conducted as before. If it contain other metals, they may be easily separated by solution in nitrous acid.

—of sulphureous ores:

In the dry way, the sulphureous ores of copper must be first pulverized, and separated as much as possible from the earthy and stony particles; then roasted,

—in the dry way.

COPPER.

roasted, to separate the sulphur and arsenic; and, lastly, melted with an equal weight of M. Tillet's flux, which consists of two parts of pounded glass, one of calcined borax, and $\frac{1}{3}$ of charcoal. More borax may be added if the ore be poor. Alkaline fluxes are hurtful in the fusion of copper ores, because the salt combines with the sulphur, and forms hepar, which dissolves part of the copper.

Treatment of
copper ores in
the large way.

In the large way, copper is roasted in a close furnace, by a slow fire, to scorify the mixtures of iron, and other substances. By repeated fusions with sulphur and charcoal, the scorified metal rises to the top, and is skimmed off. The copper in the great Hungarian mines is said to undergo fusion fourteen times before it is fit for sale. The roasted ore in the isle of Anglesey is deprived of its vitriolic salt by washing; and the copper is precipitated by means of old iron immersed in the water. This precipitated copper is, however, but a small proportion of the whole produce.

Countries
where copper
is found.

Copper is found in various parts of the world; in Spain, France, England, Norway, Hungary, Sweden, and elsewhere. The Japan copper is said to be purer, and has a greater specific gravity, than any other copper. The wire-drawers, who require copper of extraordinary ductility, use the Swedish copper. The copper mines in England are exceedingly numerous and productive. Paris mountain, on the isle of Anglesey, contains a bed of ore forty feet in thickness; and is said to produce upwards of four thousand tons of copper annually.

The

The uses of this metal are too numerous to be distinctly specified. It has for some years past been applied with great success and advantage for sheathing the bottoms of ships; and several builders have lately endeavoured to introduce it as a covering for houses. It is the lightest of all coverings; but whether it be more durable than slate, which is nearly as light, has not yet been ascertained by experience.

COPPER.

Copper applied to various uses.

C H A P. VII.

CONCERNING IRON.

IRON.
 Characters of
 iron.

IRON is a metal of a blueish white colour, of considerable hardness and elasticity; very malleable, exceedingly tenacious and ductile, and of a moderate specific gravity among metallic substances. It is much disposed to rust by the access of air, or the action of water, in the common temperature of the atmosphere. The appearance of prismatic colours on its polished surface takes place long before ignition; and at so low a temperature, that the slightest coating of grease is sufficient to prevent their appearance, by defending it from the contact of air. It may be ignited, or at least rendered sufficiently hot to set fire to brimstone, by a quick succession of blows with a hammer. When struck with a flint, or other hard stone, it emits decrepitating ignited particles, such as can be obtained from no other metal by the same means. These particles are seldom larger than the two hundredth part of an inch in diameter; and, when examined by a magnifier, are found to be hollow, brittle, and of a greyish colour, resembling the scales of burned iron. This metal is easily calcined by fire. A piece of iron wire, immersed in a jar of vital air, being ignited at one end, will be entirely consumed by the successive combustion of its parts. It requires a most intense heat to fuse it; on which account it can only be brought into the shape
 of

of tools and utensils by hammering. This high degree of infusibility would deprive it of the most valuable property of metals, namely, the uniting of smaller masses into one, if it did not possess another singular and advantageous property, which is found in no other metal except platina; namely, that of welding. In a white heat iron appears as if covered with a kind of varnish; and in this state, if two pieces be applied together, they will adhere, and may be perfectly united by forging. Iron is thought to be the only substance in nature which has the property of becoming magnetical. It is highly probable, from the great abundance of this metal, that all substances which exhibit magnetism do contain iron; but it must be confessed that there remain many experiments to be made among the earths and powders which exhibit magnetical properties, before this negative proposition, which confines magnetism to iron, can be admitted as proved.

IRON.

Characters of
iron.

When iron is exposed to the action of pure water, it acquires weight by gradual calcination, and inflammable air escapes: this is a very slow operation. But if the steam of water be made to pass through a red-hot gun-barrel, or through an ignited copper or glass tube containing iron wire, the iron becomes converted into a calx; while inflammable air passes out at the other end of the barrel. This capital experiment* may be accounted for according to the ancient and modern theories. In the ancient theory, it is supposed that the water has combined with the iron, and disengaged its phlogiston in the form of inflammable air.

Calcination of
iron by water.

Ancient the-
ory.

* Of M. Lavoisier.

IRON. and consequently that, when this calx is again revived by heating a portion of it in inflammable air with a burning glass, and water appears, at the same time that part of the inflammable air is absorbed, the iron has imbibed phlogiston, and given out its water. Clear as this explanation appears to be, the solution afforded by

Calcination of iron by water. **Modern theory** the modern theory is not less perspicuous. The maintainers of this theory reason as follows: Iron has not been shewn to be a compound substance; let us therefore consider it as a simple substance, until we possess experiments which shew the contrary. Water has been shewn to be a compound substance, by the experiment of its production, by burning dephlogisticated and inflammable air together. We may fairly therefore affirm, that the inflammable air came from the water, in which we know it to exist; and that the vital air of the water, the peculiar instrument of calcination, has combined with the iron. On the other hand, when the iron is revived in inflammable air, the water which appears is the very product of combination which was decomposed in the former instance. For the vital air quits the iron to unite in the fluid state with the inflammable air; and the iron, being set at liberty, recovers its original state; that is to say, it is revived.

Difficulty. That the iron, in the one instance, attracts vital air from the water, and disengages inflammable air; and, in the other instance, exhibits a less affinity with that substance, so as to restore it to its former combination; is a difficulty which, in the present state of our information, can only be accounted for by supposing, that the temperature in the furnace differs from that produced

duced by the burning glass; and that these affinities, like most others in chemistry, are not the same at all temperatures. This difficulty affects both theories alike; for it is not easier to account for the contrary transitions of water and phlogiston, which mutually expel each other in the old theory, than for the transitions of dephlogisticated and inflammable air in the new theory.

IRON.
Calcination of
iron by water.

Theory.

The philosophers who reject phlogiston insist, moreover, that the weight of the inflammable air produced, being deducted from the weight of the water made use of, leaves a quantity equal to the increase the iron gains by calcination; and that by burning the whole inflammable air produced, with a quantity of vital air equal in weight to the gain of the iron, a new quantity of water is recomposed, which is equal likewise to that made use of. Hence they urge, that it is infinitely more probable that the inflammable air came from the water than from the iron. The latter fact, of the recomposition, is in their favour; but the former is not. For whatever the inflammable air comes from, the first equation will be true; that is to say, if the iron give out phlogiston, and receive water, its accession of weight will be equal to the difference between the water it has received, and the phlogiston it has lost; but the reproduction of the water lost will shew that the inflammable air really corresponds with the quantity required to form*

so

* It may be urged that the two airs contain much water; and for that, as well as other reasons, their absolute quantities

IRON.

so much water, if we admit the accuracy of the experiments.

Solution of iron
in the vitriolic
acid.

The concentrated vitriolic acid scarcely acts on iron, unless it be boiling. When the acid is distilled to dryness from this metal, the retort is found to contain sublimed flowers of sulphur, and a white vitriolic mass, partly soluble in water: the product which comes over is volatile vitriolic acid, and vitriolic acid air. If the vitriolic acid be diluted with two or three parts of water, it dissolves iron readily, without the assistance of any other heat than is produced by the act of combination. During this solution, inflammable air escapes in large quantities. If heat be applied, the acid proceeds to dissolve more iron, and deposits a white saline mass, or pale vitriol of iron.

Martial vitriol.

The combination of vitriolic acid and iron, called martial vitriol, is much more soluble in hot than cold water; and therefore crystallizes by cooling, as well as by evaporation. The crystals are efflorescent, and

cannot be ascertained. But it is not required to ascertain their absolute quantities: for it is enough if the two airs in this recomposition be exactly in the same state as in the original experiment, by which the component parts of water were determined. If a certain portion of water be necessary to inflammable air in the elastic state, it must of course take it from the steam in the gun-barrel at the instant of its extrication, and not afterwards from the water of the receivers: this requires to be confirmed by an experiment over mercury. How far Dr. Priestley's experiments (Phil. Transf. lxxviii. and lxxix.) may effect the position, that water is a compound substance, cannot be clearly ascertained until it is shewn that the acid produced in burning the two airs does not arise from impurity in one or both of them. See page 95.

fall

fall into a white powder by exposure to a dry air, the iron becoming more calcined than before. A solution of martial vitriol, exposed to the air, imbibes its vital part; and a portion of the iron, becoming too much calcined to adhere to the acid, falls to the bottom in the form of ochre. The solution, as well as the crystals it affords by evaporation, are thus rendered paler than before.

IRON.
Martial vitriol.

Martial vitriol is not made in the direct way, because it can be obtained at less charge from the decomposition of martial pyrites.

The different appearances which accompany the solutions of iron in the vitriolic acid, may be accounted for according to the principles either of the ancient or modern theories. In the ancient theory, iron being supposed to contain phlogiston, or the principle of inflammability, is calcined in both cases; that is to say, it gives out phlogiston*. With the concentrated acid the solution does not take place; because the capacity of the mixture for heat, and consequently its absolute quantity of heat, is too small to supply what the increased capacity of the vitriolic acid air would require, and consequently the iron is not decomposed. But when heat is applied, the phlogiston of the iron, uniting with the basis of part of the acid, forms sulphur; which, together with another portion of the acid, rises in the form of vitriolic acid air; at the same time that the vital air of the decomposed acid unites with the calx of iron, which becomes soluble

Theory of the effects of vitriolic acid upon iron; according to the doctrine of phlogiston.

* Kirwan, in *Philos. Transact.* vol. lxxii; and *Essay on Phlogiston*, London, 1789, page 62, or page 28 of the old edition.

IRON.
Theory :

in the acid that remains : but when much water is present, as in the diluted acid, the heat is supplied from the great capacity of the water ; the phlogiston of the iron assumes the elastic form ; and inflammable air flies off, while the acid unites with the calx of iron, and forms vitriol. The decomposition of the acid in the former, and not in the latter case, is accounted for from its strong attraction to the water. A considerable heat, applied with the diluted acid, calcines the iron more perfectly ; which then either enters into the composition of pale vitriol, containing a larger proportion of acid, or falls down in the form of calx. The access of air does the same thing more gradually.

—according to
the antiphlogistic
doctrine.

In the antiphlogistic theory, iron is assumed to be a simple substance ; vitriolic acid is said to be composed of vital air and sulphur ; and water is admitted to be decomposable. When iron therefore is applied to concentrated vitriolic acid, the principles retain their order of combination at a common temperature ; but as soon as the temperature is raised, the iron becomes calcined, by attracting vital air from part of the acid, whose sulphur is therefore set at liberty, and flies off with another portion of the acid, in the form of vitriolic air ; while the remaining acid combines with part of the calx. But when the acid is more diluted, the water itself is decomposed ; its inflammable air is disengaged ; its vital air unites with and calcines the iron ; and the vitriolic acid dissolves the calx.

The necessity of heat being applied to the concentrated solution in the one case rather than the other, may be referred to the capacities of the bodies, before
and

and after the change, in either theory. But it must be confessed that the cause of the disengagement of vitriolic air in the one case, and inflammable in the other, is not so well solved. It has not been explained, upon the old theory, why the phlogiston in one case unites with the acid, and forms sulphur, and in the other flies off alone; neither has it been shewn, in the new theory, why the water should not be decomposed in the former instance, as well as the latter.

IRON.
Theory of the action of vitriolic acid on iron.

The further calcination of the iron by heat, or by exposure of the solution to the air, is accounted for, in the new theory, from the absorption of more vital air. The general fact, that a definite degree of calcination is necessary for the most perfect solution of metals in acids, depends on attractions which have not been experimentally resolved; but which, in the way of conjecture, may be as easily accounted for by one theory as by the other.

Vitriol of iron is decomposed by alkalis and by lime. Caustic fixed alkali precipitates the iron in deep green flocks, which are dissolved by the addition of more alkali, and form a red tincture. The mild alkali does not redissolve the precipitate it throws down, which is of a greenish white colour. Distillation separates the acid from martial vitriol, and leaves the brown calx of iron, called colcothar.

Precipitates of iron.

Colcothar.

Vegetable astringent matters, such as nut-galls, the husks of nuts, logwood, tea, &c. which contain the acid of galls hereafter to be described, precipitate a fine black fecula from martial vitriol, which remains suspended for a considerable time in the fluid, by the addition of gum arabic. This fluid is well known by

Black fecula, precipitated by astringents.

IRON.

Ink; its nature doubtful.

the name of ink. It appears to consist of the acid of galls, united to the calx of iron: but its nature has not been well determined; more especially by an examination of the contents of the fluid which remains after the precipitate has been completely deposited. The black fecula is not magnetical; but it is converted into a brown magnetic calx by heat. An excess of either of the three ancient mineral acids renders ink colourless; but the acetous acid, or vinegar, does not. Ink becomes blacker by exposure to the air, which acidifies more completely the principle combined with the iron; but ancient writings become more and more yellow, in consequence of the escape of the acid *. Their legibility may be restored by the addition of infusion of galls, or gallic acid. The best method of restoring

* Inks seem to fail chiefly on account of the small proportion and destructibility of the astringent principle, which Berthollet distinguishes from the gallic acid. Dr. Lewis recommends the following receipt for writing-ink (*Commerce of Arts*, page 391): One part martial vitriol, one part powdered logwood, and three parts powdered galls, are to be infused in one quart of vinegar, or white wine, or water, for each ounce of the vitriol, together with one ounce of gum arabic for each quart of the liquor; and shaken for four or five times a day, during ten or twelve days; after which it may be decanted for use.

On the above I must remark, that though vinegar affords a good black ink, yet Dr. Lewis has overlooked a great inconvenience attending its use. It acts so strongly upon the quills, that the sharpness of the extremity of a pen used with this ink soon goes off, and continually wants mending. A perfect theory of ink would probably lead to great improvements in this most useful fluid.

Ribaucourt, *Annales de Chimie*, does not approve the redundancy of astringent matter recommended by Lewis. An abstract of his experiments may be seen, under art. *INK* of the *Chemical Dictionary*.

the

the legibility of ancient writings * consists in spreading a solution of the Prussian alkali thinly with a feather over the traces of the letters; and then to touch it gently, and as nearly upon or over the letters as can be done, with a diluted acid, by means of a pointed stick.

IRON.

Manufacture of Prussian blue.

The beautiful pigment, well known in the arts by the name of Prussian blue, is likewise a precipitate afforded by martial vitriol. It has been made for considerably more than half a century; but its composition is not yet clearly ascertained. The process for making it is as follows: Calcine a mixture of equal parts of vegetable alkali and dried bullocks blood, until it ceases to emit either flame or smoke; then raise the fire, to give the mass a low red heat. Throw the matter while red-hot into as many quarts of water as there were pounds of the original mixture, and boil it for half an hour. Decant the liquid, and wash the coaly residue with more water, till it comes off almost insipid. Add this water to the former, and evaporate the whole by boiling, until it be reduced again to the former number of quarts. This is the *lixivium sanguinis*, or Prussian alkali. Prussian alkali; which, if added in a proper quantity to a solution of iron, precipitates it partly in the form of calx, and partly in the form of Prussian blue. If the marine acid be added to the precipitate, it dissolves the calciform part, and leaves the Prussian blue much purer. Hence it appears that the whole of the alkali, in the usual method of calcination with bullocks blood, or other animal substances, is not saturated with the

* Blagden, in *Philos. Transf.* vol. lxxv. page 455.

IRON.

Prussian alkali
made for che-
mical purposes.

Acid of Pruf-
sian blue.

Combinations
of Prussian
acid.

colouring matter, but that the unsaturated part of the alkali precipitates part of the iron in the calciform state; while the other part, combining with the colouring matter, falls down in the form of Prussian blue. For chemical purposes, the Prussian ley is produced, by boiling the alkali upon Prussian blue ready formed. The calx of iron is thus deprived of the colouring matter by the alkali, to which it has a greater affinity, and which it only quits when there is another acid present to unite with the alkali; as in the just-mentioned instance of the solution of iron, where a double affinity takes place. The Prussian alkali, prepared in either way, contains some iron. It can be had pure in no other way than by directly combining the pure colouring matter with a pure alkali.

The habitudes of this colouring matter denote it to be an acid. If the Prussian alkali be boiled in a retort with weak vitriolic acid, the colouring matter comes over in the form of an inflammable air, which will be absorbed by water placed in the receiver. As a portion of vitriolic acid likewise comes over, a second distillation is necessary to be made, with the addition of chalk. The vitriolic acid, by this means forming selenite, is detained; while the Prussian acid passes over totally before one-fourth of the water is distilled off.

The colouring matter of Prussian blue is not only seized by the fixed alkalis, but likewise by the volatile alkali, by lime, by magnesia, and by ponderous earth; with which it forms peculiar compounds, capable of precipitating Prussian blue, by double affinity, from the solutions of iron in acids. Various metals likewise

com-

combine with it. Alkalis, or lime, combined with the Prussian acid, are used as tests to ascertain the presence and quantity of iron in solution. But all the alkaline or earthy combinations, produced by applying those substances to Prussian blue, contain iron, which falls down in the form of the blue precipitate when an acid is added. For this reason they cannot be used in accurate experiments, unless a previous trial has been made of the quantity a known proportion of the proof liquor is capable of precipitating.

IRON.

Caution in using proof liquors.

If the dephlogisticated or aerated marine acid be mixed with the Prussian acid, the former resumes the state of common marine acid; while the latter acquires a much stronger smell, and appears to be more volatile. In this situation it does not form Prussian blue with the solutions of iron; but affords a green precipitate, which becomes blue by exposure to the light, or by the addition of volatile vitriolic acid.

Experiments on Prussian acid.

If martial vitriol be added to the dephlogisticated or aerated marine acid, and a solution of Prussian alkali be poured in, the green precipitate which is formed is again dissolved; but it may be precipitated of a blue colour by the addition of volatile vitriolic acid, or martial vitriol, or iron alone.

In the instances last mentioned we may perceive that the effects depend on the dephlogistication or addition of vital air to the Prussian acid, accordingly as we adopt the ancient or the modern theory. The green precipitate, which may be considered either as dephlogisticated Prussian blue, or as Prussian blue combined with vital air, becomes common Prussian blue

Theory.

IRON.

Theory of the
effects of aerat-
ed marine acid
on Prussian
acid.

blue by the action of light; which, as we have frequently had occasion to remark, operates in many instances in a manner contrary to that of combustion; that is to say, it either adds phlogiston, or expels vital air, or does both. By this action therefore the Prussian blue returns to its original state. The addition of volatile vitriolic acid must produce a like effect; for this acid is phlogisticated according to the old theory, or is deficient in vital air according to the new: it is therefore disposed either to phlogisticate the green precipitate, or to attract vital air from it; which is all that it requires to convert it into common Prussian blue. The same theories manifestly apply to the green precipitate, which is redissolved; for in whatever state of combination it may be supposed to remain, as to the order or arrangement of the principles which are united in the fluid, the addition of volatile vitriolic acid, or common vitriol, or iron in the metallic state, will impart phlogiston, or attract vital air; the absence of the one, or redundancy of the other of which, is supposed, according to the respective theories, to cause the difference between it and Prussian blue.

Experiment.

If the Prussian acid be impregnated more strongly with the dephlogisticated or aerated marine acid, and then exposed to the action of light, it assumes new properties. It no longer combines with iron precipitated from its solutions; its smell is entirely different from that which it before possessed; and now resembles an aromatic oil, the greatest part of it separating from the water, at the bottom of which it flows in the form of an oil. This fluid however is not inflammable.

mable. By a gentle heat it rises in the form of a vapour, not soluble in water: and in time it assumes the form of small crystals. Prussian acid cannot be restored after it has undergone these changes. Their theory is not known.

IRON.

Various experiments have been made to discover the component parts of the Prussian acid. If equal parts of pulverised charcoal and vegetable alkali be made red-hot for a quarter of an hour in a crucible, and some sal ammoniac in small pieces be then briskly stirred down into the mass, the ammoniacal vapours will soon cease. The ignited matter being then thrown into water, affords a lixivium equal to the best which is made with blood. From these, and other experiments, it was concluded that its component parts are fixed air, volatile alkali, and the principle of inflammability, or phlogiston. Later experiments appear to have decided the question somewhat more accurately. When the acid has been converted, by means of the dephlogisticated or aerated marine acid, into that state which affords a green precipitate with iron, it emits alkaline air upon the addition of lime, or a pure alkali. If the lime, or alkali, be afterwards saturated by the addition of some other acid, the Prussian acid is not disengaged, or restored, but is no where found; hence it follows, that the alkaline air was one of the principles of the Prussian acid, which is destroyed: and as the lime or alkali used in this decomposition is found to be in a mild state, that is to say, combined with fixed air, though it did not contain that substance before; it is clear that the other principle of the Prussian acid is fixed air.

The

COMPONENT PARTS OF PRUSSIAN ACID.

IRON.
Component
parts of Prus-
sian acid.

The common Prussian acid consists therefore of volatile alkali, united with the base of fixed air, or that substance which, in combination with vital air, forms the acid called fixed air. When the Prussian acid receives vital air, and is converted into the state proper to afford the green precipitate, it then appears to consist of the same principles as the mild or concrete volatile alkali, though probably in a different order of combination; and this order seems to be deranged by the addition of the lime, or the fixed alkali, which attracts those principles that form fixed air, at the same time that the principles which form volatile alkali fly off in the elastic state.

The component parts of Prussian acid will consequently be phlogisticated air, inflammable air, and fixed air, or its base; all which are afforded by animal substances; but they do not form this peculiar combination in any case yet known, excepting that in which an alkali is present when those substances are decomposed by fire *.

Action of nitrous acid on iron.

Concentrated nitrous acid acts very strongly upon iron filings, much nitrous air being disengaged at the same time. The solution is of a reddish brown, and deposits the calx of iron after a certain time; more especially if the vessel be left exposed to the air. A diluted nitrous acid affords a more permanent solution

* For a fuller account of this subject consult Scheele's Essays; the Opuscula, or Chemical Essays, of Bergman; and the Annales de Chimie, vol. i.; the latter of which contains an abstract of a valuable memoir of Berthollet, read before the Royal Academy of Sciences at Paris in the year 1787.

of iron, of a greenish colour, or sometimes of a yellow colour: neither of the solutions affords crystals; but they deposit the calx of iron by boiling, at the same time that the fluid assumes a gelatinous appearance. This magma, by distillation, affords fuming nitrous acid, much nitrous air, and some phlogisticated air; a red calx being left behind, which, in all probability, retains most of the vital air of the acid.

IRON.

If vegetable alkali be added to the nitrous solution of iron, a brown precipitate falls down; of which a small quantity is redissolved by the alkali. Mild vegetable alkali separates a yellowish calx, which soon becomes of a beautiful orange red colour. If the mixture be agitated during the effervescence, the precipitate is redissolved in much greater quantity than by the pure vegetable alkali; doubtless by the medium of the fixed air. This solution is known by the name of Stahl's martial alkaline tincture, and is of a fine red colour, which however is impaired by time. Pure volatile alkali separates a deep green and almost black precipitate from the nitrous solution of iron. The mild volatile alkali redissolves the iron, which it separates from the acid; and forms an alkaline tincture of a more lively colour than that of Stahl.

Precipitates of iron from nitrous acid.

Martial alkaline tinctures.

Diluted marine acid rapidly dissolves iron, at the same time that a large quantity of inflammable air is disengaged, and the mixture becomes hot. In this, as well as in the vitriolic solution of iron, the same quantity of alkali is said to be required to saturate the acid as before the solution; whence it is inferred that the acid is not decomposed, but that the calcination

Action of marine acid on iron.

IRON.

tion is effected by the vital air of the water : whence also it appears to follow, that the inflammable air must be afforded from the decomposed water, and not from the metal. It must however be remarked, that this fact, as well as most of those upon which the rejection of phlogiston, or the inflammable principle, is grounded, are controverted by the philosophers who maintain the existence of that principle.

Marine solution of iron.

The marine solution of iron is of a yellowish green colour, and is much more permanent than the solutions of that metal in the vitriolic or nitrous acids; though, like all the other solutions of iron, it deposits its metal by exposure to the air. By evaporation it assumes the consistence of syrup, in which needle-formed and deliquescent crystals appear. Some chemists affirm, that the acid quits the iron by distillation, though much more difficultly than either the nitrous or vitriolic acid; but this interesting experiment has not been made since the improvements of chemistry have led philosophers to attend to such products as appear in the permanently elastic state.

Precipitates.

The marine solution of iron is decomposed by lime and by alkalis; but the precipitates are more easily reduced to the metallic state than those afforded by other acids. Liver of sulphur, hepatic air, and astringents, decompose this, as well as the other solutions of iron; and the pure Prussian alkali throws down a very fine blue precipitate.

Action of fixed air on iron:

Fixed air, dissolved in water, combines with a considerable quantity of iron, in proportion to its mass.

—and vinegar.

Vinegar scarcely dissolves it, unless by the assistance of the air.

In the dry way, this metal does not combine with earths, unless it be previously calcined; in which case it assists their fusion, and imparts a green colour to the glass. It appears to combine with alkalis by fusion. Nitre detonates strongly with it, and becomes alkalinized. Sal ammoniac is decomposed by it. Two parts of iron filings, triturated with one part of sal ammoniac, and exposed to distillation, afford about one part of liquid volatile alkali, contaminated by a small portion of iron. Some inflammable air comes over in this distillation, either from the iron, or from the water contained in the sal ammoniac: the residue consists of iron united to marine acid. A medical preparation is made by subliming sal ammoniac from a small portion of iron filings; which gives part of the salt a yellow colour. The calx of iron decomposes sal ammoniac by seizing its acid, even in the cold.

IRON.

Action of
earths, &c. on
iron.

Sulphur combines very readily with iron, in the dry, and even in the humid way, though neither of these substances is scarcely at all soluble in water. A mixture of iron filings and flowers of sulphur being moistened, or made into a paste, with water, becomes hot, swells, adheres together, breaks, and emits watery vapours of an hepatic smell. If the mixture be considerable in quantity, as for example, one hundred pounds, it takes fire in twenty or thirty hours, as soon as the aqueous vapours cease. This effect may be explained without difficulty in a general way, though the circumstances require to be more minutely examined:—Iron, sulphur, and water, are placed in contact. The iron is very sparingly soluble in water*;

Combination
of iron with
sulphur in the
humid way.Spontaneous
inflammation.

* Annales de Chimie, vol. i. 220.

IRON.
 Theory of the
 inflammation
 of iron and sul-
 phur :

—by the anti-
 phlogistic hy-
 pothesis.

and the sulphur is probably soluble in a small degree, as may be judged by its becoming soft in that fluid. In the ancient theory, it may be said that the sulphur combines with the calx of the iron, and expels its inflammable air or phlogiston. The heat must be deduced, in any theory, from the change of capacity, or rapid commotion, produced in the act of union. This heat volatilizes part of the sulphur, together with the inflammable air; and if the temperature be sufficiently elevated, these substances will take fire, at the moment of their extrication, by the assistance of the air of the atmosphere. In the new theory, the explanation will be nearly the same. The iron and the sulphur, being considered as simple substances, tend to combine with each other, through the medium of vital air, which calcines the iron, and is supposed to be afforded by decomposition of the water. The same decomposition extricates inflammable air from the water. This, together with the sulphur, forms hepatic air; which, flying off at the temperature of ignition, takes fire by combination with the air of the atmosphere. In this theory it may further be added, that, as sulphur and water, in contact, at an elevated temperature, afford inflammable air, which is explained by the supposition of vital air combining with the sulphur, there would be an increase of inflammation from this cause. Some doubt however may be entertained, whether sulphur be more combustible than inflammable air at any temperature, since hepatic air deposits sulphur when detonated with vital air; which must, in all probability, depend on the latter being less combustible at the temperature of inflammation. On the whole

whole it appears, that facts and observations are wanting, rather than probable theories; and that it is scarcely necessary to pursue this inquiry more minutely in the way of argumentative disquisition. The spontaneous combustion of iron and sulphur with water, is evidently an effect of the same kind as the decomposition of pyrites.

IRON.

Page 144.

Sulphur combines very readily with iron by fusion; and produces a compound of the same nature as the pyrites, and exhibiting the same radiated structure when broken. If a bar of iron be heated to whiteness, and then touched with a roll of sulphur, the two substances combine, and drop down together in the fluid state. It is necessary that this experiment should be made in a place where there is a current of air to carry off the fumes; and the melted matter, which may be received in a vessel of water, is of the same nature as that produced by fusion in the common way, excepting that a greater quantity of sulphur is fused by the contact of the bar of iron. The experiment of combining iron and sulphur together by fusion, has not been made with an attention to the volatile products, if any be extricated. As neither of these substances contains water, and both are supposed, in the new theory, to be simple bodies, the experiment might, perhaps, afford an interesting result.

If equal parts of phosphoric glass, and iron filings, together with one-sixteenth of a part of pulverized charcoal, be fused together, the mixture is very brittle, white in its fracture, and of a striated and granulated texture. This combination of iron with

Phosphorus and iron.

Y

phos-

- IRON.** phosphoric acid is found in the iron produced from bog ores, which abound in the remains of decayed vegetables. It is the cause of brittleness in the iron when cold; which occasions that kind of iron to be called cold short iron. Phosphorated iron was at first taken to be a peculiar metal; and was called siderite by Bergman.
- Cold short iron.**
- Siderite.**
- Metallic combinations.** Iron unites with gold, silver, and platina. When heated to a white heat, and plunged in mercury, it becomes covered with a coating of that metal. Long trituration of mercurial amalgams likewise causes a coating to adhere to the ends of iron pestles; small steel springs, kept plunged beneath the surface of mercury in certain barometers, become brittle in process of time: and the direct combination of* iron and mercury in the form of an amalgam may be obtained by triturating the filings with twice their weight of alum; then adding an equal weight or more of mercury, and continuing the friction with a very small quantity of water till the union is completed. Iron and tin very readily unite together; as is seen in the art of tinning iron vessels, and in the fabrication of those useful plates of iron, coated with tin, which are generally distinguished by the simple name of tin alone. The chief art of applying these coatings of tin consists in defending the metals from calcination by the access of air. After the iron plates are scraped, or rendered very clean by scouring with an acid, they are wetted with a solution of sal ammoniac, and plunged into a vessel containing melted tin; the surface of which is covered with pitch or
- Tinning of iron plates.**

* Vogel, in Crell's Annals, ii. 103. Eng. transf.

IRON.

tallow, to preserve it from calcination. The tin adheres to and intimately combines with the iron to a certain depth, which renders the tinned plates less disposed to harden by hammering, than before, as well as much less disposed to alter, by the united action of air and moisture. The process for tinning of iron vessels does not essentially differ from that which has already been described of copper vessels. Iron does not unite with bismuth, at least in the direct way. As nickel cannot be purified from iron without the greatest difficulty, it may be presumed that these substances would readily unite, if the extreme infusibility of both did not present an obstacle to the chemical operator. Arsenic forms a brittle substance in its combination with iron. This semi-metal, which is so abundant in the mineral kingdom, is said to be the cause of the brittleness which some specimens of iron possess when hot, though malleable when cold. Iron, thus contaminated, is distinguished by workmen by the name of red short iron. Cobalt forms a hard mixture with iron, which is not easily broken. The inflammability and volatility of zinc present an obstacle to its combination with iron. It is not improbable, however, but that clean iron filings would unite with zinc, if that metal were kept in contact with them for a certain time, in a heat not sufficient to cause it to rise; for it has been found that zinc may be used in the operation of coating iron in the same manner as tin. Antimony unites with iron, and forms a hard brittle combination, which yields, in a slight degree, to the hammer. The combination of sulphur, and the regulus of antimony, which is commonly known by the name of antimony, is decomposed

Combinations
of iron with
metallic sub-
stances.

IRON.

Combinations
of iron with
metallic sub-
stances.

by virtue of the greater affinity of the iron to the sulphur. For this purpose, five ounces of the points of nails from the farriers may be made red-hot in a crucible; one pound of pulverized ore of antimony must then be thrown into the crucible, and the heat quickly raised to fuse the whole. When the fusion is perfect, an ounce of nitre in powder may be thrown in to facilitate the separation of the scoriae. After the mass is cooled, the antimony is found separate at the bottom of the crucible, while the iron remains in combination with the sulphur and alkali. If the proportion of the iron be considerably greater than five ounces to the pound of antimonial mineral, the regulus will be alloyed with iron. Manganese is almost always united with iron in the native state. Wolfram forms a brittle whitish-brown hard alloy, of a compact texture, when fused with white crude iron.

The habitudes of iron with the regulus of molybdena are not known.

Native iron,
and its ores.

Iron is the most diffused, and most abundant, of metallic substances. Few mineral bodies, or stones, are without an admixture of this metal. Sands, clays, and the waters of rivers, springs, rain, or snow, are scarcely ever perfectly free from it. The parts of animal and vegetable substances likewise afford iron in the residues they leave after incineration. It has been found native, in large masses, in Siberia*, and in the internal parts of South America. This metal however in its native state is scarce: most iron is found

* See Bergman's *Essays*; Magellan's improved edition of Cronstedt's *Mineralogy*; and the *Philos. Trans.* lxxviii. 37.

in the calciform state, in ochres, bog ores, and other friable earthy substances, of a red, brown, yellow, or black colour. The hæmatites, or blood stones, are likewise calciform ores of iron: these are either of a red colour, or blue, yellow, or brown. This useful metal is so abundant, that whole mountains are composed of iron stone; whereas other metals usually run in small veins. Besides the calciform ores of iron, which are either nearly pure, or else mixed with earths, as in spars, jasper, boles, basalt, &c. iron is mineralized with sulphur, as in the pyrites; with arsenic, in the white pyrites; or with both. An iron ore is likewise found, of a blue colour, and powdery appearance, which is thought to be of the same nature as Prussian blue. The coaly iron ores contain bitumen. The magnet, or loadstone, is an iron ore, whose constitution has not yet been accurately examined. Iron is also found in combination with the vitriolic acid, either dissolved in water, or in the form of vitriol.

IRON.
Ores of iron,

To analyse the ores of iron in the humid way, they must be reduced to a very subtle powder, and repeatedly boiled in marine acid. If the sulphureous ores should prove slow of solution, a small quantity of nitrous acid must be added to accelerate the operation. The iron being thus extracted, the insoluble part of the matrix only will remain. Prussian alkali, being added to the decanted solution, will precipitate the iron in the form of Prussian blue. This precipitate, when washed and dried, will be equal in weight to six times the quantity of metallic iron it contains; and from this iron four parts in the hundred must be deducted, to allow for the iron which is contained in the

Humid analysis
of iron ores.

IRON.
 Ores of iron.

Prussian alkali itself. But as this alkali, and every other preparation containing the Prussian acid, does not constantly afford the same quantity of iron, the most exact way, in the use of such preparations, consists in previously dissolving a known quantity of iron in vitriolic acid; and precipitating the whole by the addition of the Prussian alkali. This result will afford a rule for the use of the same alkali in other solutions. For as the weight of the precipitate obtained in the trial experiment, is to the quantity of iron which was dissolved and precipitated; so is the weight of the precipitate obtained from any other solution, to the quantity of iron sought.

If the iron be united to any considerable proportion of zinc or manganese, the Prussian blue must be calcined to redness, and treated with pale nitrous acid, which will take up the calx of zinc. The manganese may then be dissolved by nitrous acid, with the addition of sugar; and the remaining iron, being dissolved by marine acid, and precipitated by mild mineral alkali, will afford 225 grains of precipitate for every 100 grains of metallic iron.

Analysis in the
 dry way.

To examine the ores of iron in the dry way, the only requisite is fusion, in contact with charcoal.—For this purpose, eight parts of pulverized glass, one of calcined borax, and half a part of charcoal, are to be well mixed together. Two or three parts of this flux, being mixed with one of the pounded ore, and placed in a crucible, lined with a mixture of a little clay and pounded charcoal, with a cover luted on, is to be urged with the strong heat of a smith's forge for half an hour. The weight of the ore, in this experiment,

ment, should not exceed 60 grains. Other processes for determining the contents, or metallic product, of iron ores, are instituted by performing the same operations in the small, as are intended to be used in the large way.

IRON.

In the large iron works, it is usual to roast or calcine the ores of iron previous to their fusion; as well for the purpose of expelling sulphureous or arsenical parts, as to render them more easily broken into fragments of a convenient size for melting. The mineral is melted, or run down, in large furnaces from 16 to 30 feet high; and variously shaped, either conical or elliptical, according to the opinion of the iron-master. Near the bottom of the furnace is an aperture for the insertion of the pipe of large bellows, worked by water or steam, or of other machines for producing a current of air; and there are also holes at proper parts of the edifice, to be occasionally opened, to permit the scoriæ and the metal to flow out, as the process may require. Charcoal, or coke, with lighted brushwood, is first thrown in; and when the whole inside of the furnace has acquired a strong ignition, the ore is thrown in by small quantities at a time, with more of the fuel, and commonly a portion of limestone, as a flux: the ore gradually subsides into the hottest part of the furnace, where it becomes fused; the earthy part being converted into a kind of glass; while the metallic part is reduced by the coal, and falls through the vitreous matter to the lowest place. The quantity of fuel, the additions, and the heat, must be regulated, in order to obtain iron of any desired quality; and this quality must likewise, in the first

Smelting of iron
in the large
way.

IRON.

product, be necessarily different, according to the nature of the parts which compose the ore.

States of iron.

The three kinds of crude iron.

The iron which is obtained from the smelting furnaces is not pure ; and may be distinguished into three states :—white crude iron, which is brilliant in its fracture, and exhibits a crystallized texture, more brittle than the other kinds, not at all malleable, and so hard as perfectly to withstand the file : grey crude iron, which exhibits a granulated and dull texture when broken ; this substance is not so hard and brittle as the former, and is used in the fabrication of artillery, and other articles which require to be bored, turned, or repaired : and black cast iron, which is still rougher in its fracture ; its parts adhere together less perfectly than those of the grey crude iron : this is usually fused again with the white crude iron.

Refining of iron.

Whenever crude iron, especially the grey sort, is fused again with contact of air, it emits sparkles, loses weight, and becomes less brittle. In order to convert it into malleable iron, it is placed on a hearth, in the midst of charcoal, urged by the wind of two pair of bellows. As soon as it becomes fused, a workman continually stirs it with a long iron instrument. During the course of several hours it becomes gradually less fusible, and assumes the consistence of paste. In this state it is carried to a large hammer, the repeated blows of which drive out all the parts that still partake of the nature of crude iron so much as to retain the fluid state. By repeated heating and hammering more of the fusible iron is forced out ; and the remainder, being malleable, is formed into a bar, or other form, for sale.

Crude

Crude iron loses upwards of one-fourth of its weight in the process of refining.

IRON.

Purified, or bar iron, is soft, ductile, flexible, malleable, and possesses all the qualities which have been enumerated in this chapter, as belonging exclusively to iron. When a bar of iron is broken, its texture appears fibrous; a property which depends upon the mechanical action of the hammer, while the metal is cold. Ignition destroys this fibrous texture, and renders the iron more uniform throughout; but hammering restores it.

Bar iron.

If the purest malleable iron be bedded in pounded charcoal, in a covered crucible, and kept for a certain number of hours in a strong red heat (which time must be longer or shorter, according to the greater or less thickness of the bars of iron), it is found that by this operation, which is called cementation, the iron has gained a small addition of weight, amounting to about the hundred and fiftieth, or the two hundredth part; and is remarkably changed in its properties. It is much more brittle and fusible than before. Its surface is commonly blistered when it comes out of the crucible; and it requires to be forged, to bring its parts together into a firm and continuous state. This cemented iron is called steel. It may be welded like bar iron; but its most useful and advantageous property is that of becoming extremely hard when ignited, and plunged in cold water. The hardness produced is greater in proportion as the steel is hotter, and the water colder. The colours which appear on the surface of steel slowly heated, are yellowish white, yellow, gold colour, purple, violet, deep blue, yellowish

Iron converted into steel by cementation.

Hardening.

IRON.

Tempering.

The processes
for hardening
and tempering
of steel.

yellowish white; after which the ignition takes place.

These signs direct the artist in tempering or reducing the hardness of steel to any determinate standard. If steel be too hard, it will not be proper for tools which are intended to have a fine edge, because it will be so brittle that the edge will soon become notched; it may even be rendered friable by too much heat; on the contrary, if it be too soft, it is evident that the edge

will bend or turn. Some artists ignite their tools, and plunge them in cold water; after which they brighten the surface of the steel upon a stone: the tool being then laid upon charcoal, or upon the surface of melted lead, or placed in the flame of a candle, gradually acquires the desired colour; at which instant they plunge it into water. If a hard temper be desired, the piece is dipped again, and stirred about in the cold water as soon as the yellow tinge appears. If the purple appear before the dipping, the temper will be fit for gravers, and tools used in working upon metals; if dipped while blue, it will be proper for springs, and for instruments used in the cutting of soft substances, such as cork, leather, and the like; but if the last pale colour be waited for, the hardness of the steel will scarcely exceed that of iron. When soft steel is heated to any one of these colours and then plunged in water, it does not acquire nearly so great a degree of hardness as if previously made quite hard and then reduced by tempering. The degree of ignition required to harden steel, is different in the different kinds. The best kinds require only a low red heat. The harder the steel, the more coarse and granulated its fracture will be; and as this is not completely remedied by the sub-

sequent

sequent tempering, it is advisable to employ the least heat capable of affording the requisite hardness.

IRON.

It is a circumstance worthy of remark, that steel has a less specific gravity when hardened than when soft; but there are no circumstances, upon which a probable connection between these two properties, namely the increased hardness, and the diminished specific gravity, can be made out.

The usual time required for the cementation of a small bar of steel is from six to ten hours; but in the large way they employ four or five days. If the cementation be continued too long, the steel becomes porous, brittle, of a darker fracture, more fusible, and incapable of being forged or welded. On the contrary, steel cemented with earthy infusible powders, is gradually reduced to the state of forged iron again. Simple ignition produces the same effect; but is attended with calcination of the surface. The texture of steel is rendered more uniform by fusing it before it is made into bars: this is called cast steel; and is rather more difficultly wrought than common steel, because it is more fusible, and is dispersed under the hammer if heated to a white heat.

It is often found of advantage in the arts to convert the outside of any tool or implement into steel after it is nearly finished. This is called case hardening. The following is among the receipts given for this purpose:

Cow's horn or hoof is to be baked, or thoroughly dried, and pulverized. To this add an equal quantity of bay salt. Mix them with stale chamber ley, or white wine vinegar. Cover the iron with this mixture,

Process.

IRON.

ture, and bed it in the same in loam, or inclose it in an iron box. Lay it then on the hearth of the forge to dry and harden. Then put it in the fire, and blow till the lump have a red heat, and no higher, lest the mixture be burned too much. Take the iron out, and immerse it in water, to harden.

Comparison of
steel and crude
iron.

When we consider the operations by which crude iron is brought into the malleable state, then converted into steel, and afterwards into a fusible metal, which is not malleable; we may perceive that steel-making is a kind of inversion of the process of refining iron, as practised in the first instance. When the calx of iron is mixed together in the smelting furnace, with combustible matter and glass, it will either be completely or partially revived, according to the management of the process. Much of the coal will however be so enveloped with the vitreous matter as to remain unburned: and the reduced iron, with which it may be in contact, will be in the same situation as forged iron in the cementing pot; that is to say, it will be in contact with coal at a very elevated temperature, and defended from the air. From the great infusibility of iron, it may reasonably be concluded that the reduced metal does not flow into the bottom of the furnace, until the charcoal has converted it into a fusible matter similar to steel, by the same action which takes place in cementation, whatever that action may be. Hence it must follow, that the various specimens of crude or cast iron will differ in their qualities, as well on account of the degree of cementation they have undergone, as the degree of reduction which has taken place among the metallic parts,

IRON.

Page 327.

parts, which are carried down, and form the whole mass. Since the coal, in the process of cementation, communicates or adds weight to the iron; and since crude iron, as well as steel, exhibits sparkles, and is more easily burned than other iron; it may therefore be concluded that, in the process of refining, that part of the inflammable substance which had united with the metal is burned, and leaves the iron much less fusible than before. Stirring the mass multiplies the contacts of the air with the burned substances; these surfaces of contact will therefore successively afford thin coats of infusible metal. In this manner it is found, that if a large piece of crude iron be exposed to heat in a wind-furnace, the external part will be deprived of its fusibility during the time required to produce a strong heat in the whole mass; and the internal part will be melted, and run out, leaving the shell behind. Iron which is of the consistence of paste may therefore be considered, like any other paste, as a mixture of a fluid with a solid. It will be easily understood that the forging will bring the parts of difficult fusion together, and extrude the less refined and fluid parts: it will also be evident that this operation is not likely to drive out the whole of the fusible matter. When the iron has arrived at that state wherein the quantity of fibre or tough iron is sufficient to answer the mechanical purposes to which it is intended to be applied, the artist will consider it as sufficiently refined; and the residue of fusible iron contained in the bar answers, in all probability, the valuable purpose of connecting these infusible masses together. Thus we find that forged iron appears as if

Consideration
of the effects of
heat in refin-
ing iron.

Probable cause
of the property
of welding.

IRON.

if covered with a varnish, when urged to a white heat; we find that this varnish is more abundant in steel; and that iron and steel may be respectively welded together by application in this state; an effect which it would be very difficult to account for, in this most infusible of metals, if it were not for such an admixture. But cast steel, steel over-cemented, and crude iron, appear to be in the state of all other metals, platina excepted. They cannot be welded, because welding implies a partial fusion; or an effect similar to the glueing or uniting of solids by the application of a fluid, which afterwards becomes consistent. And if it be true that platina possesses this valuable property, it seems reasonable to infer that it must also consist of two metallic substances of different degrees of fusibility.

Platina.

Crude iron
and steel.

Crude iron, and steel of an uniform texture, consist therefore of a fusible combination of iron with the combustible substance of the coal, or something which is imparted from it; the crude iron differing from the steel simply in being over-cemented, and less pure, on account of the admixture of metallic calx, which can scarcely, perhaps, be avoided in the large process. It appears therefore that crude iron must pass through the state of steel before it can become forged iron; and consequently that the fabrication of steel from this last is a circuitous process, which can only be repaid by the absence of those unreduced parts which may exist in the crude iron. At some forges, however, where the ore, the flux, the fuel, and the management, are adapted to each other, the produce affords steel, when duly refined. At other manufactories,

Processes for
refining crude
iron, and making
steel in a
direct way.

nufactories, the crude iron is either refined, or converted into steel, by running it into thin plates, which are stratified with charcoal, and burned in a close furnace. In this way, the metal is refined by degrees, without undergoing fusion; and if the heat be raised to that of cementation, the iron will not only be reduced, but converted into steel. In the forges of Carinthia the grey crude iron is also converted either into soft iron or steel, according to the management of a somewhat similar process. The iron is fused in a large melting pot; and a small quantity of water being thrown upon the surface of the metal, causes a thin plate to congeal, which is taken off; and, by continuing the operation, the greatest part of the fused iron becomes converted into plates. To produce steel, these plates are again fused, and kept a long time in an elevated heat; at the same time that the metal is defended from the contact of the air by a sufficient quantity of the vitreous slag. To produce soft iron, the plates are exposed to a continued roasting, while the air is constantly renewed by means of two pair of bellows. The extensive surface of the plates renders it unnecessary to use that agitation, or stirring, which is required when fused crude iron is refined. In these processes it is evident, that the same matter in the crude iron, which it obtained in the smelting furnace, is employed, and supplies the place of the charcoal of cementation in forming the steel; and, on the other hand, that this substance, which prevented the crude iron from being soft, tough, and infusible, is burned away, together with a portion of the iron itself, while the remainder is left in a much purer state.

These

IRON.

The existence of plumbago in crude iron and steel; ascertained in the dry way.

These are the facts observed at the furnaces. But the observations and inquiries of the chemist must be carried farther, in order to determine what it is that iron gains or loses at the time of its conversion into its various states. It is found that crude iron approaches towards the soft state, not only by heating with exposure to air, which burns the combustible addition, but likewise by fusion, without the free access of air. In this case, when the fusion has been complete, and the cooling gradual, it is found that a black substance is thrown up to its surface, which is more abundant the greyer or blacker the iron; and the same black substance is observed to coat the ladles of forged iron, which are used to take out the metal, and pour it into moulds for casting shot and other articles. It appears therefore that the heated iron, like other heated fluids, is capable of holding a larger quantity of matter in solution than when cold; and that a portion of this black substance separates during the cooling, whether by the gradual effect of surrounding bodies or by the contact of the ladle, in the same manner as various salts are separated, in part, from water by a diminution of temperature. From chemical analysis, as well as from its obvious characters, this black substance is found to be plumbago, or the material used to make pencils, and commonly known by the name of black-lead.

Plumbago extricated from iron in the humid way.

The presence of this black matter is likewise exhibited by dissolving steel, or crude iron, in acids, in which plumbago is insoluble, and therefore remains behind in the form of a powder. Hence likewise is deduced the cause of the black spot which remains upon steel, or crude iron, after its surface has been corroded

corroded by acids; for this spot consists of the plumbago which remains after the iron has disappeared by solution.

IRON.

Solution in the vitriolic or marine acids, not only exhibits the plumbago contained in iron, but likewise possesses the advantage of shewing the state of its reduction by the quantity of inflammable air which is disengaged: for whether this aërial fluid be supplied by the phlogiston of the iron, or from the decomposed water, it is agreed on all hands that its quantity, in like circumstances, is proportional to that of the iron which is converted into calx. There are considerable differences between the various products of the smelting furnace in these respects; but it is found that the white crude iron affords the least quantity of inflammable air in proportion to its bulk, and leaves a moderate portion of plumbago; the grey crude iron affords more inflammable air, and more plumbago, than the white; and the softest bar iron affords most inflammable air of any, and little or no plumbago. The quantities of inflammable air*, at a medium, by ounce measures, were 62, afforded by 100 grains of the white crude iron; 71 by the grey crude iron; and 77 by the malleable iron.

Quantities of plumbago, and of inflammable air, afforded by various kinds of iron.

Hence it may be inferred that, in the white crude iron, the processes of reduction and cementation are both carried to a less extent than in the grey crude iron, which is produced by means of a stronger heat,

Degrees of reduction and cementation in iron.

* Acad. Par. 1786, pages 166, 167. The numbers in the text are given as a rough measure; for, in fact, there can be no medium.

IRON.

excited with a larger quantity of fuel: and that the reduction of grey crude iron is still less perfect than that of the soft bar iron; though this last, by the refining in an open vessel, is so far from being more cemented, that it scarcely contains any plumbago at all.

Inaccuracies.

It must be admitted, however, that the solution in acids serves only to support these general conclusions, in conjunction with the facts observed in the dry processes; but cannot accurately shew either the quantities of inflammable air or plumbago afforded by the several kinds of iron. For the plumbago, as it becomes disengaged, floats on the top of the vitriolic acid; where it gradually disappears, though insoluble in that acid. It must therefore be taken up by the inflammable air; and it is found that the volume of this air is diminished by the absorption. Hence there is a double source of inaccuracy from the loss of plumbago, and the contraction of the inflammable air.

Plumbago.

As plumbago appears to be a compound of iron and combustible matter, and as the properties and effects of iron, in its various states, cannot be well understood without a reference to those of this substance, it will be expedient to give an account of it in this place, instead of referring it to the next section.

Characters of plumbago.

Plumbago, or black lead, is a well-known substance, of a black colour, and shining appearance, when cut. Its texture is rather scaly; but its fracture exhibits a granular and dull appearance. None of the specimens have any considerable hardness. This mineral is found in England, Germany, France, Spain, and Africa; but the

the sort best adapted for making pencils comes chiefly from Borrowdale in Cumberland. For this purpose, it is carefully sawed into narrow slips, or pieces, not more than one-tenth of an inch thick; which are glued between two half cylinders of cedar wood. An inferior kind of pencils is made by the Jews, by mixing the powder or saw-dust with gum arabic, or fusing it with resin or sulphur; and pressing or pouring it into the cavities of reeds. The powder of plumbago, with three times its weight of clay, and some hair, makes an excellent coating for retorts; and the black lead or Hessian crucibles are composed of the same materials.

IRON.

Plumbago is not subject to alteration by exposure to the action of air or water; and it is insoluble in acids.

In closed vessels it is either entirely, or nearly, unalterable by the strong heat of a furnace; but by continued ignition, and occasional stirring in a shallow vessel, under a muffle, it is gradually dissipated, or burned, leaving a residue of calx of iron, of about one-tenth of the original weight. It detonates with nitre in a red heat; ten parts of this salt are required to one of plumbago before the whole will be decomposed, and exhibit no residue of plumbago when the alkali is dissolved in water.

The aerial product of this detonation is found to consist of a mixture of one-third fixed air; and the rest air which maintains combustion: the alkali contains fixed air; and some of the nitre is driven up by the heat. In order to shew that the fixed air came from the plumbago, and not from the nitre, the first analyser * of this substance

Experiments
tending to dis-
cover the com-
ponent parts of
plumbago.

* Scheele. See his Essays, Eng. transf. Essay xiii.

IRON,

detonated tin, antimony, and sulphur, respectively, with nitre, and obtained no fixed air: and, still more to place the inference beyond a doubt, he exposed plumbago to distillation, with twice its weight of dry acid of arsenic: the acid was reduced to the state of white calx and sublimed; and pure fixed air came over. Similar results were had with the calces of mercury and lead; the metals were revived, and fixed air was expelled. When pulverized plumbago was distilled with caustic fixed alkali by a strong heat, the volatile product was inflammable air; and the remaining alkali contained fixed air.

Phlogistic theory.

From these, and other facts, he concluded, that plumbago is a compound of phlogiston and fixed air, with a little iron, which he supposed to be accidental. The existence of the phlogiston was judged to be proved by its detonation with nitre, as well as by the revival of the acid of arsenic and the metallic calces, and the extrication of inflammable air by alkali: he inferred the quantity of phlogiston in this substance to be twice as much as in charcoal; because it requires twice the quantity of nitre for its detonation. The presence of fixed air was deduced from the aerial products in all the distillations but the last; and from the mild state of the alkalis, in those trials wherein they were used.

Antiphlogistic theory of plumbago.

The antiphlogistic philosophers * consider plumbago as a compound of iron and the acidifiable base of fixed air, which they call carbone, because it exists most abundantly in charcoal. The difficulty of burn-

* Acad. Par. 1785, pag. 132, et seq.

IRON.

ing or decomposing it, is considered as a consequence of the combination of its parts, which are less disposed to unite with vital air, than either would be if alone. The same difficulty accounts for the large proportion of nitre required to deflagrate with it completely; a quantity required, not because there is much combustible matter to be burned, but because a long continued and elevated heat is necessary; by which means much of the nitre is decomposed, and its vital air flies off, without having been employed in the combustion, as appears by the two thirds of the elastic product, which will support the flame of a candle. The other facts are easily adapted to this theory. By detonation with nitre it affords fixed air, because the combustible base is acidified by the vital air of the nitre. The arsenical acid, and metallic calces, are reduced by the abstraction of the vital air they contain; which vital air, combining with the acidifiable base contained in the plumbago, converts it into the fixed air, or acid, which flies off: And, lastly, in the distillation of plumbago with humid alkali, a decomposition of the water takes place: its inflammable air flying off; and its vital air, combining with the acidifiable base, as before, forms fixed air, which unites with the alkali, and renders it mild.

The chief difference in the matter of fact between these theorists appears to consist in the iron; which the latter consider as a necessary part of the combination; by means of which they account for its difficult combustibility. Since plumbago does really contain iron, it may be considered as a compound of a similar nature to the martial pyrites. Thus in the pyrites iron

Resemblance
between plum-
bago and py-
rites.

Z 3

is

IRON.
 Page 151, 153.

is united to sulphur; which the phlogistian philosophers assert to be a compound of vitriolic acid (or its base) and phlogiston, while their opponents take the sulphur to be a simple substance, capable of acidification by the addition of vital air: and so likewise plumbago is a compound of iron, united to another substance; which the phlogistians assert to be fixed air, combined with phlogiston; at the same time that the other party, rejecting the inflammable principle, affirm that it is the simple acidifiable base, which will form fixed air when vital air is added to it. We see therefore that it is the explanation, and not the facts, which forms the object of contention.

Recapitulation
 of the facts re-
 lating to the
 states of iron.

Since crude iron, then, contains the base of fixed air in combination, of which it may be deprived by heat with access of vital air, which converts it into the acid state; and since it again recovers that base by cementation with charcoal, there can be no doubt but the plumbago is afforded by the fuel, it being highly probable that iron is necessary to its separate existence. It appears also that the reduction of the metallic calx takes place first at a lower temperature; and that the combination of the base of fixed air follows at a greater heat. Whence, in the refining of iron, the plumbago is first burned, and the iron remains reduced; and, in the cementation of bar iron, the metal is converted into steel, with blisters on its surface; which most probably arise from fixed air formed by the vital air of some portions of unreduced calx, uniting with the acidifiable base from the charcoal. And, lastly, as iron holds this acidifiable base, or phlogisticated acid, in solution, so likewise it may not be separable from this
 me-

Refining.

Cementation.

metallic solvent, without carrying a portion with it; in the same manner as salts, which crystallize in water, always take up part of the solvent in the formation of their crystals. IRON.

It would require many volumes to enumerate the Uses of iron. leading uses of iron. This most valuable of metals is applied to so many and such important uses, that we cannot look round us without seeing its effects. When we contemplate the innumerable effects of human industry, and ask ourselves the simple question, could this have been done without iron? there is not a single instance which will not immediately shew its value. It is indeed difficult to form a notion, how civilized society could exist without it.

CHAP. VIII.

CONCERNING TIN.

TIN.
 Characters of
 tin.

TIN is a metal of a yellowish white colour, considerably harder than lead, scarcely at all sonorous, very malleable, though not very tenacious. Wires cannot be made of it; but, under the hammer, it is extended into leaves called tin-foil, which are about one-thousandth of an inch thick; and might easily be beaten to less than half that thickness, if the purposes of trade required it. The process for making tin-foil consists simply in hammering out a number of plates of this metal, laid together upon a smooth block, or plate of iron. The smallest sheets are the thinnest. Its specific gravity is less than that of any other malleable metal. Long before ignition, it melts at about the 410th degree of Fahrenheit's thermometer; and, by a continuance of the heat, it is slowly converted into a white powder by calcination. Like lead, it is brittle when heated almost to fusion; and exhibits a grained or fibrous texture, if broken by the blow of a hammer; it may also be granulated by agitation at the time of its transition from the fluid to the solid state. The calx of tin resists fusion more strongly than that of any other metal; from which property, it is useful to form an opaque white enamel, when mixed with pure glass in fusion. The brightness of its surface, when scraped, soon goes off by exposure to the air; but it
 is

is not subject to rust, or corrosion, by exposure to the weather.

TIN.

Concentrated vitriolic acid, assisted by heat, dissolves half its weight of tin, at the same time that vitriolic acid air escapes in great plenty. By the addition of water a calx of tin is precipitated. Vitriolic acid, slightly diluted, likewise acts upon this metal; but if much water be present, the solution does not take place. In the vitriolic solution of tin there is an actual formation, or extrication, of sulphur, which renders the fluid of a brown colour whilst it continues heated, but subsides by cooling. The tin is likewise precipitated in the form of a white calx by a continuance of the heat, or by long standing without heat. This solution affords needle-formed crystals by cooling.

Solution of tin
in vitriolic acid.

Nitrous acid and tin combine together very rapidly, without the assistance of heat. Most of the metal falls down in the form of a white calx, extremely difficult of reduction; and the small portion of tin which remains suspended, does not afford crystals, but falls down, for the most part, upon the application of heat, to inspissate the fluid. The strong action of the nitrous acid upon tin produces a singular phenomenon, which is happily accounted for by the modern discoveries in chemistry. Mr. De Morveau * has observed that, in a solution of tin by the nitrous acid, no elastic fluid was disengaged; but that volatile alkali was formed. This alkali must have been produced by the phlogisticated air of that part of the nitrous acid

—in nitrous
acid.

Singular effect.

* Kirwan on Phlogiston, 2d edition, p. 234.

which

TIN. which was employed in affording pure air to calcine the tin. The phlogisticated air must therefore have combined with inflammable air : but whether this inflammable air was afforded by a decomposition of the water of the menstruum, or whether it came from the phlogiston of the tin, is a question that must remain undetermined until decisive experiments have been made for the establishment of one or the other of the two theories, which at present divide the chemical world.

Solution of tin
in marine acid :

The marine acid dissolves tin very readily, at the same time that it becomes of a darker colour, and ceases to emit fumes. A slight effervescence takes place with the disengagement of a fetid inflammable gas. Marine acid suspends half its weight of tin, and does not let it fall by repose. It affords permanent crystals by evaporation. If the tin contain arsenic, it remains undissolved at the bottom of the fluid.

—in dephlogis-
ticated marine
acid :

Dephlogisticated marine acid dissolves tin very readily, and without sensible effervescence. The solution itself does not appear to differ from the foregoing.

—in aqua regia.

Aqua regia, consisting of two parts nitrous and one marine acid, combines with tin with effervescence, and the development of much heat. In order to obtain a permanent solution of tin in this acid, it is necessary to add the metal by small portions at a time ; so that the one portion may be entirely dissolved before the next piece is added. Aqua regia, in this manner, dissolves half its weight of tin. The solution is of a reddish brown, and in many instances assumes the form of a concrete gelatinous substance. The addition of water sometimes produces the concrete form in this

solution,

solution, which is then of an opal colour, on account of the calx of tin diffused through its substance. The uncertainty attending these experiments with the solution of tin in aqua regia seems to depend upon the want of a sufficient degree of accuracy in ascertaining the specific gravities of the two acids which are mixed; the quantities of each, and of the tin, together with that of the water added. It is probable that the spontaneous assumption of the concrete state depends upon water imbibed from the atmosphere. The solution of tin in aqua regia is used by dyers to heighten the colours of cochineal, gum lac, and some other red tinctures, from crimson to a bright scarlet, in the dyeing of woollens.

M. Hermstædt has succeeded in the actual acidification of this metal, by treating it with the marine and nitrous acids. He dissolves pure tin in pure marine acid, and boils this solution with nitrous acid (distilled from manganese) until the red vapours cease to appear. The fluid, which is then limpid, is exposed to distillation until the whole of the marine and nitrous acids have been dissipated. The white remaining mass is soluble in three parts of water, and is the acid of tin. A red heat converts this matter into a yellow transparent substance, neither acid nor soluble in water; but it regains both properties by a few weeks exposure to the air*.

The acetous acid scarcely acts upon tin. The operation of other acids upon this metal has been little inquired into.

* Journal de Phys. xxxv. 391. Nov. 1789.

When

TIN.

The fuming
liquor of Liba-
vius.

Adet's exami-
nation of the
fuming liquor
of Libavius.

When equal parts of an amalgam of tin and mercury, and of corrosive sublimate, are triturated together, and the mixture exposed to distillation in a retort, by a very gentle heat; a colourless fluid first comes over, which is followed by a thick white fume, which becomes condensed into a transparent liquor, called the fuming liquor of Libavius, on account of the copious fumes it emits when the vessel that contains it is opened. On account of the considerable volatility of this liquid, it rises, partly in the form of flowers, to the top of the bottle in which it is put; so that, in the course of several months, it becomes entirely closed. The composition and effects of this liquid were but imperfectly known until lately, when Mr. Adet made several ingenious experiments upon it. By exposing this liquid under receivers containing dry air, over mercury, he found that the volatile fluid arose, and lined the vessel with crystals, when water was present; though very few crystals were formed when the air was as dry as it could be made. He observed likewise, that when water was added to the fuming liquor of Libavius, it became solid, and ceased to emit fumes. A precise quantity of water is required to produce this effect in the most perfect manner. If the quantity of water be too small, the liquor retains more or less of its disposition for the fluid state; and if it be too considerable, the fluidity of the water prevails. By several trials he found that the due proportion of water to be added to the fuming liquor of Libavius was as 7 to 22. A kind of ebullition, or escape of bubbles, was produced during the combination; which, on examination, was found to arise from the

the escape of the air previously contained in the fluid water. He found likewise that this concrete substance, when rendered fluid by an increase of temperature, was capable of dissolving more tin, without the disengagement of inflammable air. After the concrete substance was saturated with tin, it could no longer be sublimed, but might be made to undergo a red heat; during which time there was an escape of vapours, consisting of tin combined with the marine acid; and, after a strong heat, the residue was a white calx of tin. It appeared therefore that the liquor of Libavius, rendered concrete by water, and saturated with tin, resembles in its properties the common solution of tin in the marine acid.

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Adet's examination of the fuming liquor of Libavius.

From these circumstances, Mr. Adet concludes that the tin, by stronger affinity, combines with the aerated or dephlogisticated marine acid of the corrosive sublimate with which it is heated; that this combination contains no water; and that, as it abounds with a substance of such extreme volatility as that aerated acid, its freezing point is very low, insomuch that it is habitually fluid; that the addition of water, in a due proportion, alters the freezing point, and renders it concrete at a common temperature; and, lastly, that the state of the marine acid in this substance is that which is called aerated, or dephlogisticated; which is proved, as well from the experiments which ascertain that state in corrosive sublimate, as from similar experiments with the fuming liquor, which, as has been observed, is capable of dissolving more tin without disengaging inflammable air. The fuming liquor of Libavius has therefore the same relation to the common

TIN. mon solution of tin as corrosive sublimate has to calomel*.

The residue, after the distillation by which the fuming liquor of Libavius is produced, consists of tin combined with the marine acid, calomel, and running mercury, which sublime into the roof and neck of the retort; and at the bottom is found an amalgam of mercury and tin, covered with a saline combination of marine acid with tin, and such other metals as the tin may have been adulterated with. Much information may be derived from the foregoing experiments of Mr. Adet respecting the phenomena produced when tin is dissolved in aqua regia.

Habitudes of tin, with earths and neutral salts :

Earthy substances do not appear to affect this metal in the dry way. It detonates very rapidly with nitre, and becomes converted into a calx, which partly combines with the alkali. All the vitriolic salts are decomposed by tin. The tin becomes calcined, and the vitriolic acid converted into sulphur, either by the phlogiston of the metal, according to the ancient theory; or by the subtraction of its vital air, according to the modern theory. This sulphur appears to combine with the alkali, or earth of the salt, with which it forms an hepar that dissolves part of the calx.

—with sal ammoniac.

Sal ammoniac is very readily decomposed by tin. Alkaline and inflammable air are disengaged; and a concrete marine salt remains behind, which, in some measure, resembles the fuming liquor of Libavius. The volatile alkali, or alkaline air, which escapes, is

* Annales de Chimie, i. 1, &c.

difen-

TIN.

disengaged by virtue of the superior affinity of the calx of tin with the marine acid, at the temperature of the experiment. The inflammable air, which likewise flies off, is a consequence of the calcination of the tin; and will be derived either from the phlogiston of the tin, or the decomposition of the water, according to the theory which may be applied in the explanation. Notwithstanding the facility with which this metal decomposes sal ammoniac, there is an inconvenience resulting from its use, which depends on the great fusibility of this metal; in consequence of which, it cannot be intimately mixed with the sal ammoniac, but remains at the bottom of the vessel in the fluid state; while part of the sal ammoniac eludes its action, and is sublimed entire.

If the crystals of the saline combination of copper with the nitrous acid be grossly powdered, moistened, and rolled up in tin-foil, the salt deliquesces, nitrous fumes are emitted, the mass becomes hot, and suddenly takes fire. In this experiment* the rapid transition of the nitrous acid to the tin is supposed to produce or develop heat enough to set fire to the nitrous salts; but by what particular changes of capacity, has not been shewn.

If sulphur, in powder, be added to about five times its weight of melted tin, the two substances combine, and form a black compound, which takes fire, and is much less easily fused than the tin itself. The mass is brittle, and of a needled texture.

The combination of tin and sulphur, called aurum

Spontaneous
decomposition
and inflammation
of metallic
salts.

Combination of
tin with sul-
phur.

Aurum musi-
vum.

* Of Dr. Higgins. *Philos. Trans.* lxxiii. p. 137.

musivum,

TIN.
 Aurum musivum.

musivum, is thus made: Melt twelve ounces of tin, and add to it three ounces of mercury; triturate this amalgam with seven ounces of sulphur, and three of sal ammoniac. Put the powder into a matraass, bedded rather deep in sand, and keep it for several hours in a gentle heat; which is afterwards to be raised, and continued for several hours longer. If the heat has been moderate, and not continued too long, the golden-coloured scaly porous mass, called aurum musivum, will be found at the bottom of the vessel; but, if it has been too strong, the aurum musivum fuses to a black mass of a striated texture. This process is thus explained: As the heat increases, the tin, by stronger affinity, seizes, and combines with, the marine acid of the sal ammoniac; while the alkali of that salt, combining with a portion of the sulphur, flies off in the form of an hepar. The combination of tin and marine acid sublimes, and is found adhering to the sides of the matraass. The mercury, which served to divide the tin, combines with part of the sulphur, and forms cinnabar, which also sublimes; and the remaining sulphur, with the remaining tin, forms the aurum musivum, which occupies the lower part of the vessel. It must be admitted, however, that this explanation does not indicate the reasons why such an indirect and complicated process should be required to form a simple combination of tin and sulphur.

Combination of
 tin with phosphorus.

When tin is heated with phosphoric acid and charcoal, the metal appears to be very little changed. A combination, however, seems to take place; for the phosphorus burns on the surface of the metal when heated by the blow-pipe.

Tin

Tin unites with bismuth by fusion ; and becomes harder and more brittle, in proportion to the quantity of semi-metal added. With nickel it forms a white brilliant mass. It cannot easily be united in the direct way with arsenic, on account of the volatility of this semi-metal ; but, by heating it with the combination of the arsenical acid and vegetable alkali, the salt is partly decomposed ; and the tin, combining with the acid, becomes converted into a brilliant brittle compound, of a plated texture. It is thought that all tin contains arsenic ; and that the crackling noise which is heard upon bending pieces of tin is produced by this impurity. Cobalt unites with tin by fusion ; and forms a grained mixture, of a colour slightly inclining to violet. Zinc unites very well with tin, increasing its hardness, and diminishing its ductility, in proportion as the quantity of zinc is greater. This is one of the principal additions used in making pewter, which consists, for the most part, of tin. The best pewter does not contain above one-twentieth part of admixture, which consists of zinc, copper, bismuth, or such other metallic substances as experience has shewn to be most conducive to the improvement of its hardness and colour. The inferior sorts of pewter, more especially those used abroad, contain much lead, have a blueish colour, and are soft. The tin usually met with in commerce in this country has no admixture to impair its purity, except such as may accidentally elude the workmen at the mines. But the tin met with in foreign countries is so much debased by the dealers in that article, especially the Dutch, that pewter and tin are considered

TIN.

Metallic mix-
tures.

Pewter.

Mistake of foreigners respecting English tin.

A a

abroad

TIN.

abroad as the same substance. Regulus of antimony forms a very brittle, hard, mixture with tin; the specific gravity of which is less than would have been deduced by computation from the specific gravities and quantities of each, separately taken. Wolfram, fused with twice its weight of tin, affords a brown spongy calx, which is somewhat ductile.

Native tin.

Tin is scarcely ever found native. Native tin may be analysed, in the moist way, by the application of nitrous acid, which calcines the tin, and dissolves the other metals it may contain. One hundred and forty grains of the washed and dried calx are equivalent to one hundred grains of metallic tin. The metallic admixtures may be separated from the nitrous acid by methods adapted to their respective properties; which may be easily gathered from what has already been observed in the humid analysis of the metals before treated of.

Calciform ores of tin.

The calciform ores of tin are—tin spar, which is generally of a whitish or grey colour, sometimes greenish or yellowish, semi-transparent, and crystallized in a pyramidal form, or irregularly—opaque brown or black tin ore, crystallized, and embodied in quartz, fluor, or mica, or mixed with white and yellow pyrites; these ores contain a mixture of iron—the reddish yellow, or garnet ore, which contains more of iron than of tin—and the tin stone, vulgarly called loadstones, which contain still less tin.

Tin ores containing arsenic;

and sulphur.

It was formerly supposed that tin was frequently mineralized by arsenic; but it is now admitted that the arsenic, which may be contained in tin, is afforded by the matrix. The scarcity of sulphureous tin ores

was

TIN.

was likewise considered, till lately, as a very singular fact, on account of the facility with which that substance unites to tin: such combinations, however, have since been found. The native aurum musivum, from Siberia, is of this kind: and a very considerable vein of tin in combination with sulphur, and an admixture of copper and iron, has been found in Cornwall*. The analysis of tin ores in the humid way is an object of some difficulty; because they are not acted upon effectually either by the vitriolic, nitrous, or marine acids, or by aqua regia. The method of Bergman is as follows: The ore must be reduced to a very subtile powder by levigation and elutriation.

This last process consists in agitating any powder in water, which is heavy enough to sink in that fluid. The particles will be resisted in their descent, according to the surfaces they oppose against the fluid. It is scarcely necessary to observe, that a larger body presents a less surface to be resisted, than the same body would oppose if it were divided into parts. For this reason, when a powder, consisting of particles of the same density, but different magnitudes, is agitated in a slighter fluid, the largest pieces come first to the bottom: and hence the method of elutriation enables us to assort the various particles of a powder according to their magnitudes, by first agitating the fluid, and successively decanting it into different vessels. Thus, for example, if the water be decanted five seconds after the agitation, it will leave a powder behind it; if it

Process of elutriation described and explained.

* See Magellan's Cronstedt, p. 637. The contents of one specimen were 30 parts sulphur, 41 tin, 43 copper, 2 iron, and stony matrix.

TIN.

Putty.

Analysis of tin
ores, in the hu-
mid way :

be again decanted, at the end of five seconds more, the second vessel will contain a much finer powder than the foregoing ; and, by a third decantation, a still more subtile powder will be obtained. This is the method applied in the preparation of the white calx of tin called putty, and used for polishing fine metallic speculums, and the object lenses of telescopes ; and in this way the tin ore, to be analysed, may be reduced to a very subtile powder, by levigating and again washing the coarse residue which subsides in the first vessel. It may be observed, that the successive decantations are unnecessary where the very finest powder only is wanting ; because this may be as well obtained by suffering the water to stand a sufficient time before it is decanted off at first. To the very subtile powder of tin ore thus afforded, a quantity of concentrated vitriolic acid must be added, and kept in a strong digesting heat for several hours. A small portion of concentrated marine acid must be poured into this when cold. A strong effervescence takes place, with considerable heat, and the escape of marine acid air, which has been deprived of its water by the vitriolic acid. After the expiration of an hour or two, some water must be added, and the clear liquor decanted. The same operation must be repeated with the residuum, until the acids can dissolve no more : and nothing will then remain but the stony matrix. The solution, when precipitated by means of mild alkali, will afford 100 grains of metallic tin for each 132 grains of precipitate, when washed and dried. If the precipitate do not consist of pure tin, but contain copper or iron, it must be calcined for an hour in

in a red heat; then digested in nitrous acid, which will take up the copper; and afterwards in marine acid, which will dissolve the iron.

TIN.

In the dry way, after pulverization, and separation ^{—in the dry way.} of the stony matter by washing, the tin ores may be hastily fused with twice their weight of a mixture of pitch and calcined borax, in a crucible lined with charcoal, and covered; or the ore may be mixed with twice its weight of tartar, one part of black flux, and half a part of resin. This mixture being then divided into three parts, each part must be successively projected into a crucible ignited to whiteness, which must be immediately covered as soon as the portion thrown in ceases to flame.

The operation of reducing tin ores in the large ^{Reduction of tin in the large way.} way, is conducted upon similar principles. When impure, they are cleansed from foreign admixtures, by sorting, pounding, and washing. A slight previous roasting renders the stony parts more friable; and, when arsenic is contained in the matrix, it is driven off by a strong heat, continued for a short time; the ore being frequently stirred, to prevent its running together by fusion. In the smelting of the ore, care is taken to add a larger quantity of fuel than is usual in the reviving of other metals; and to avoid a greater heat than is necessary to reduce the ore, in order that the loss by calcination may be prevented as much as possible.

Tin is a metal which, as far as our present information extends, is not very much diffused. It is ^{Countries which afford tin.} found in Bohemia and Saxony, and on the island of Malacca in the East-Indies. But the largest quantities,

TIN.

ties, at least for the European consumption, are found in England, particularly in the county of Cornwall. This island has been famous for its tin mines from the remotest periods of history; and would not, probably, have been frequented by the ancient Phœnician navigators, if they had not been attracted hither by the great plenty of tin with which it abounds. Several etymologists have endeavoured to shew that the name of Britain is derived from a word common to the Syrian and Chaldean languages, denoting tin; but on this no great stress can be laid.

Uses.

The uses of tin are very numerous, and so well known, that they scarcely need be pointed out. Several of them have already been mentioned. The tinning of iron and copper, the silvering of looking-glasses, and the fabrication of a great variety of vessels and utensils for domestic and other uses, are among the advantages derived from this metal.

C H A P. IX.

CONCERNING BISMUTH.

BISMUTH is a semi-metal, of a yellowish or reddish-white colour, little subject to change in the air. It is somewhat harder than lead, and is scarcely, if at all, malleable; being easily broken, and even reduced to powder by the hammer. The internal face, or place of fracture, exhibits large shining plates, disposed in a variety of positions: thin pieces are considerably sonorous. At a temperature not exceeding the 460th degree of Fahrenheit it melts; and its surface becomes covered with a greenish, grey, or brown calx. A stronger heat ignites it, and causes it to burn with a small blue flame; at the same time that a yellowish calx, known by the name of flowers of bismuth, is driven up. This calx appears to rise in consequence of the combustion; for it is very fixed, and runs into a greenish glass when exposed to heat alone. Bismuth, urged by a strong heat, in a closed vessel, sublimes entire. This semi-metal crystallizes very distinctly, when gradually cooled.

The vitriolic acid has a slight action upon bismuth, when it is concentrated; and boiling. Vitriolic acid air is exhaled, and part of the bismuth is converted into a white calx. A small portion combines with the vitriolic acid, and affords a deliquescent salt in the form of small needles.

BISMUTH.
 Solution in ni-
 trous acid.

The nitrous acid attacks bismuth with the greatest rapidity and violence; at the same time that much heat is extricated, and a large quantity of nitrous air escapes. The solution, when saturated, affords crystals as it cools; the salt detonates weakly, and leaves a yellow calx behind, which effloresces in the air. Upon dissolving this salt in water, it renders that fluid of a milky white, and lets fall a calx of the same colour.

White calx, or
 magistery of
 bismuth.

The nitrous solution of bismuth exhibits the same property when diluted with water; most of the metal falling down in the form of a white calx, called magistery of bismuth. This precipitation of the nitrous solution, by the addition of water, is the criterion by which bismuth is distinguished from all other metals. The magistery, or calx, is a very white and subtile powder, when prepared by the addition of a large quantity of water: it is used as a paint for the complexion, and is thought gradually to impair the skin. The liberal use of any paint for the skin seems, indeed, likely to do this; but there is reason to suspect, from the resemblance between the general properties of lead and bismuth, that the calx of this semi-metal may be attended with noxious effects similar to those which the calces of lead are known to produce.

Solution in
 marine acid.

The marine acid does not readily act upon bismuth. It is necessary that the acid should be concentrated, and kept a long time in digestion upon it; or that it should be distilled from the semi-metal. The residue when washed with water, affords a saline combination, which does not easily crystallize, but may be

sublimed in the form of a soft fusible salt, called butter of bismuth. The marine solution of bismuth likewise affords a precipitate of calx by the addition of water. Marine acid seizes the calx of bismuth, when added to its solution in nitrous acid; and forms a compound of sparing solubility, which falls to the bottom. Alkalis likewise precipitate its calx; but not of so beautiful a white colour as that afforded by the affusion of pure water.

BISMUTH.

The effects of earths and alkalis upon bismuth, in the dry way, have been little attended to. Nitre calcines it, with scarcely any perceptible detonation. Sal ammoniac is not decomposed by bismuth in the metallic state, though its calx readily combines with the marine acid of that salt, and disengages the volatile alkali. Sulphur unites with bismuth by fusion, and forms a blueish grey brilliant mass, of a needle-formed texture.

Habitudes of
bismuth with
earths, salts,
sulphur:

This semi-metal unites with most metallic substances; and renders them, in general, more fusible. When calcined with the imperfect metals, its glass dissolves them, and produces the same effect as lead in cupellation; in which process, it is even said to be preferable to lead.

—and metallic
substances.

Bismuth is used in the compositions of pewter, in the fabrication of printers types, and in various other metallic mixtures.

It is sometimes found native, and may be analysed, in the humid way, by solution in nitrous acid, and precipitation, by the addition of water; which throws down 113 grains of calx for every 100 of metallic bismuth. It is likewise found in the calciform state; and

Native bismuth
and its ores.

BISMUTH.

Reduction of
bismuth ores.

and mineralized by sulphur, of a grey colour, resembling galena, but heavier. These ores may also be analysed by nitrous acid, like the foregoing.

Bismuth is easily separable, in the dry way, from its ores, on account of its great fusibility. It is usual, in the processes at large, to throw the bismuth ore into a fire of wood; beneath which a hole is made in the ground to receive the metal, and defend it from calcination. The same process may be imitated in the small way, in the examination of the ores of this metal; nothing more being necessary than to expose it to a moderate heat in a crucible, with a quantity of reducing flux; taking care, at the same time, to perform the operation as speedily as possible, that the bismuth may be neither calcined nor volatilized.

CHAP. X.

CONCERNING NICKEL.

NICKEL is a reddish-white metallic substance, of great hardness, and of an uniform texture; very difficult to be purified, and always magnetical, whence it has been supposed to contain iron in its purest state. It is malleable, and is scarcely more fusible than pure iron. Its calces are of a green colour.

NICKEL.
Characters.

This metallic substance has not been applied to any use: and the chief attention of those chemists who have examined it has been directed to obtain it in a state of purity; which, however, has not yet been accomplished. It is found either native or calciform; but most commonly mineralized in combination with arsenic, sulphur, cobalt, and iron, in the ore called k pfer nickel, or false copper. This is of a reddish yellow, or coppery colour; of a texture either uniform, granular, or scaly; bright in its fracture, and almost always covered with a green efflorescence of calx. Most of the sulphur and arsenic may be driven off by long-continued roasting, and the occasional addition of charcoal, which prevents the arsenic from being rendered more fixed by calcination; and the green calx which remains may be fused by the strongest heat of a smith's forge, together with two or three times its weight of black flux. The regulus thus obtained is of

Treatment of
the ores of
nickel.

NICKEL. of a reddish-white colour, and brittle; but is very far from being pure. Repeated calcinations for many hours, and reductions, scarcely deprive the regulus of iron; and it is still highly magnetic, when purified to such a degree as to possess considerable malleability. Combination with sulphur, with liver of sulphur, detonation with nitre, and solution in the volatile alkali and vitriolic acid, did not deprive it of its magnetism.

Purest regulus
of nickel:

When the regulus *, obtained by scorification and reduction, was combined with sulphur, and reduced again after the dissipation of the sulphur by strong heat, and the addition of charcoal, to promote the volatility of the arsenical contents; and this process was three times repeated; the reduced metal was so infusible, as not to run into a mass by the strongest heat of a smith's forge, continued for three quarters of an hour. Its colour was then whitish, mixed with a glittering kind of red; it was strongly magnetical; of a specific gravity of 8.66; and a globule of one line in diameter was extended by the hammer into a plate of upwards of three lines in diameter: so that it is, properly speaking, an entire metal, and not a semi-metal. It afforded a blue solution with the volatile alkali; and in nitrous acid its solution was of a full green.

—is an entire
metal.

Action of vitri-
olic acid.

Concentrated vitriolic acid acts upon the regulus of nickel, and corrodes it. The residue, after distillation of the acid, is a greyish powder; part of which is in the saline state, and affords green crystals by solution in water and evaporation.

* Bergman on Nickel, in vol. ii. of his Essays.

NICKEL.

The nitrous solution of this metal affords saline crystals. Alkalis precipitate it, and redissolve the precipitate. Nitre detonates with nickel in the dry way. Sulphur readily combines with it by fusion, as does likewise arsenic; and both adhere very pertinaciously to it, as has been already shewn.

Nickel has been thought to be a modification of iron. This conclusion is grounded chiefly on its magnetism, and the consideration of the very remarkable and different properties iron is known to be capable of assuming, in its several states. Others have supposed it to be an alloy of copper with various metallic admixtures. The blue colour it affords with volatile alkali, is the chief circumstance which gave rise to this opinion. But it has been very properly observed *, that many of the known metals would scarcely have endured more severe trials than this substance has undergone, without shewing indications, at least as strong, against the supposition of their being distinct bodies, as any afforded by nickel; and consequently, that so long as no one is able to produce this metal from pure iron or copper, and to explain in an intelligible way the process by which it can be generated, we must continue to regard it as a peculiar substance, possessing distinct properties. The general opinions of chemists concur in admitting the force of this reasoning.

Whether
nickel be truly
a peculiar metal.

* Bergman, ii. 264.

CHAP. XI.

CONCERNING ARSENIC.

ARSENIC.

Characters.

ARSENIC in the metallic state, or the regulus of arsenic, is of a bright yellowish white colour, subject to tarnish, and grow black, by exposure to air. It is brittle, and when broken exhibits a laminated texture. In close vessels it sublimes entire; but burns with a small flame, if respirable air be present.

White calx of arsenic :

The arsenic met with in commerce has the form of a white calx. It is brought chiefly from the cobalt works in Saxony, where zaffre is made. Cobalt ores contain much arsenic, which is driven off by long torrefaction. The ore is thrown into a furnace resembling a baker's oven, with a flue, or horizontal chimney, nearly two hundred yards long; into which the fumes pass, and are condensed into a greyish or blackish powder. This is refined by a second sublimation in close vessels, with a little pot-ash, to detain the impurities. As the heat is considerable, it melts the sublimed flowers into those crystalline masses which are met with in commerce.

—is in a saline state.

The calx of arsenic is so far in the saline state, as to be soluble in about eighty times its weight of water at the temperature of 60° , or in fifteen times its weight of boiling water.

Regulus.

The regulus may be obtained from this calx, either by quickly fusing it together with twice its weight of soft soap, and an equal quantity of alkali, and pouring it

it out, when fused, into an hot iron cone; or by mixing it in powder with oil, and exposing it in a matrafs to a sand heat. This process is too offensive to be made but in the open air, or where a current of air carries off the fumes. The decomposed oil first rises; and the regulus is afterwards sublimed, in the form of a flaky metalline substance.

ARSENIC.

Regulus.

Vitriolic acid does not attack the regulus of arsenic, nor its calx, when cold; but, if it be boiled upon this semi-metal, vitriolic acid air is emitted, a small quantity of sulphur sublimes, and the arsenic is reduced to the calciform state. Boiling vitriolic acid dissolves the calx of arsenic; but scarcely retains any portion of it when cold. The calx of arsenic is considerably less volatile when vitriolic acid is present, or mixed with it; but it is said that washing deprives it of the acid, and restores its properties.

Action of vitriolic acid :

Nitrous acid readily attacks and calcines the regulus of arsenic: it likewise dissolves the calx of this semi-metal, in considerable quantity, by the assistance of heat; and affords a crystallized deliquescent salt by evaporation, which does not detonate on red-hot coals. The calx of arsenic is acidified by the action of nitrous acid distilled from it.

—of nitrous acid :

Boiling marine acid dissolves the regulus, and also the calx of arsenic; but affects it very little when cold. This solution affords precipitates upon the addition of alkalis.

—of marine acid :

The dephlogisticated or aerated marine acid converts the calx of arsenic into arsenical acid.

—of aerated acid.

The calx of arsenic acts, in many instances, like an acid. It decomposes nitre by distillation; the nitrous acid

acid

ARSENIC. acid flying off, and the arsenical salt of Macquer remaining behind. In this process, the nitrous acid appears to acidify the calx. Quadrangular nitre is affected in the same manner. When the white calx of arsenic is distilled with sulphur, volatile vitriolic acid flies off, and a combination of a yellow colour, called orpiment, is produced; which appears to consist of sulphur, united to regulus of arsenic; that is to say, part of the sulphur receives vital air from the calx; to which, according to the ancient system, it communicates phlogiston: and in this manner the sulphur becomes converted into vitriolic acid; while the arsenical calx is reduced, and combines with the rest of the sulphur. The combination of sulphur and arsenic which has been fused, is of a red colour; and known by the name of realgar, or realgar. Realgar appears to be less volatile than orpiment, or the yellow combination; for it remains at the bottom, while the other sublimes; but in what respect they differ from each other has not been well ascertained. It is not improbable but that the orpiment may contain the calx in a more reduced state than the realgar. A strong heat converts orpiment into realgar.

Distillation of
calx of arsenic
with sulphur.

Orpiment and
realgar.

Liver of sul-
phur.

Fixed alkalis.

Saline liver of sulphur dissolves the calx of arsenic; but more readily attacks the regulus.

Watery solutions of fixed alkalis dissolve the calx of arsenic; and, if they be loaded with it by means of heat, a brown tenacious mass is produced, which acquires solidity, has a disagreeable smell, and is called hepar of arsenic. Mineral acids precipitate part of the arsenic; but a portion of it, being acidified, adheres more tenaciously to the alkali. The acids occa-

sion

tion no precipitation from the solution of arsenic in the volatile alkali. It is not easy to explain what happens in this case, without further experiments. The solutions of calx of arsenic in alkalis differ much in their properties from the combination which is produced when the nitrous salts are decomposed by its means. This difference is accounted for from the consideration that it is the calx of arsenic in the first case, and the acid in the latter, which combines with the alkalis.

ARSENIC.

Combination of calx of arsenic, with alkalis:

A solution of the calx of arsenic acts upon metals —with metals. in the humid way, most probably in consequence of its approach to the acid state.

The acid of arsenic being applied to the filings of the metals, in a long-necked flask, to prevent its reduction, acts upon several of the metals in a digesting heat. Gold and platina are scarcely acted upon. Silver is not attacked by digestion; but when the acid comes to be fused, the metal is dissolved, and affords a colourless glass, which is nearly transparent; soluble in water, with the loss of greatest part of the silver, which subsides in the form of a brown powder, containing a minute portion of the acid; and reducible, like the other precipitates of silver, by mere heat. Mercury is not attacked by the arsenical acid, in the heat of digestion; but when the acid and mercury are urged in a retort, by an heat which is near melting the vessel, part of the mercury combines with the acid, and forms a yellowish mass of extremely difficult fusion; very fixed, and insoluble in water. Diluted nitrous and vitriolic acids have scarcely any effect on it, but marine acid readily dissolves it. This solution, by evaporation to dryness, and distillation, affords

Action of arsenical acid—

—on gold, platina:
—silver:

—mercury.

B b

corro-

ARSENIC.
 Action of arse-
 nical acid on
 copper ;

—on iron :

—on lead.

corrosive sublimate, and the residue is arsenical acid : whence it follows, that the mercury in the arsenical combination must have been perfectly calcined. Copper is dissolved by the arsenical acid in digestion, and affords a green solution. One part of copper filings, mixed with two of dry arsenical acid, affords a blue mass by fusion, at an elevated degree of heat, which is soluble in water ; and then proves to be the same combination as was produced by digestion. The watery solution lets fall a light blue powdery matter, consisting of a combination of copper with arsenical acid. Iron likewise is attacked by this acid during digestion ; and the whole solution at last grows gelatinous, if the digestion be performed in an open vessel. If the digestion be performed in a long-necked or close vessel, it does not become gelatinous ; but will afterwards become so, if exposed to the air. In the dry way, when one part of iron filings is distilled with four of acid of arsenic, the mass makes a great effervescence towards the end ; and, when it becomes dry, it takes fire upon increasing the heat ; arsenic and regulus of arsenic being sublimed, and a black friable residuum being left at the bottom, which contains but little acid of arsenic. In this process it appears that the iron, which is a metal very much disposed to combustion or calcination, suddenly deprives the arsenical acid of its vital air, and reduces it to the state of calx and regulus ; at the same time that, according to the ancient hypothesis, phlogiston passes from the metal to the acid. Little effect is produced upon lead by digestion with the arsenical acid ; but the combination takes place by fusion in the dry

dry way, which affords a semi-opake glass. When this is boiled in distilled water, the lead falls down in the form of a white powder, containing arsenical acid, but which does not afford arsenic by heat, unless charcoal be added. Tin, digested with arsenical acid, grows black at first; afterwards becomes covered with a white powder; and, at last, the whole mass becomes gelatinous. In the dry way, one part of tin filings, with two of the acid, heated in a retort, took fire when ignited: and the calx of regulus of arsenic immediately sublimed, leaving a limpid solution of tin; which, when cooled, was of a milky colour. This, when dissolved in distilled water, deposited a white calx, which contained very little acid of arsenic.

ARSENIC.

Action of arsenical acid on tin:

Zinc is the only metallic substance which effervesces when digested with the arsenical acid. The zinc grows black; and the transparency of the acid is destroyed by a quantity of black powder; which, on examination by burning on a red-hot iron, proves to be regulus of arsenic. This precipitated regulus soon defends the zinc from farther solution. The air which escapes during the effervescence is inflammable, holding regulus of arsenic in solution, which it deposits on burning. Either of the chemical theories will serve to explain these effects: for the zinc is calcined by receiving the vital air of the acid; while it is supposed to give out phlogiston enough to reduce the acid basis to a regulus, and to afford the inflammable air which escapes. Or, in the other theory, it will be said that the zinc, having a strong tendency to combine with vital air, and become calcined, cannot decompose water

—on zinc.

ARSENIC. at a moderate temperature, unless an acid be present, to remove the coating of calx by solution as fast as it is formed, which mere water cannot do. This therefore is the first consequence of the mutual action of water, zinc, and the acid; namely, vital air quits the water to unite with the zinc, and inflammable air flies off at the same time that the acid combines with the calx of zinc. But of the two metallic bases, which are here combined by the intermedium of vital air, the zinc has a strong tendency to calcination, and the arsenic to become revived: it appears therefore, from the facts, that the zinc, attracting the vital air most strongly, becomes still more calcined, and consequently less soluble; while the arsenic is reduced by the loss of its vital air. Whence it must follow, that the metallic zinc which remains, being enveloped with calx of zinc and metallic arsenic, can no longer be acted on by the acid and water, which still continue undecomposed. On this, and similar occasions, it cannot however be too often repeated to the chemical student, that theories ought to be cautiously followed, as of use in the arrangement of facts, and in directing the path to future investigations; that discriminating phenomena ought to be earnestly sought after, because of infinitely more value than the most ingenious speculations; and that an attachment to system, though it frequently gives life and energy to the exertions of genius, is in general a certain source of prejudices, which disable the enquirer from pursuing the search after truth, and fix his mind upon words instead of things.

Action of arsenical acid on zinc.

Theory.

Caution respecting theories.

In

In the dry way, when one part of the filings of zinc was mixed with two of the arsenical acid, and distilled, the mass took fire, with a very bright inflammation, as soon as the retort became red-hot. The vessel was burst by the explosion; and in its neck were found regulus of arsenic, and flowers of zinc. This effect may be explained from the same considerations as were applied to the combustion which takes place, in like circumstances, with iron.

ARSENIC.
Action of arsenical acid on zinc:

Bismuth is acted upon by the arsenical acid in digestion. Water precipitates a powder from the solution, which consists of acid of arsenic, combined with calx of bismuth. In the dry way, bismuth is calcined by this acid, but not dissolved; a little arsenic being sublimed: and if water be added to the cooled mass, the acid is taken up, but the calx remains. Regulus of antimony is affected nearly in the same manner as bismuth, in the humid way; but, in the dry way, an inflammation takes place at the time of fusion. By digestion with cobalt, the acid of arsenic assumed a rose colour; but much of the cobalt remained undissolved. The whole mass being distilled to dryness, and fused, afforded glass of a violet colour, and semi-transparent. Nickel communicates a green colour to this acid by digestion; a quantity of green powder, mixed with arsenic, being precipitated: the arsenic may be separated by a gentle heat. In the dry way, the acid combines with nickel, and forms a yellow mass, with grey streaks upon it, resembling a vegetation. By boiling in water, the acid is taken up, and a yellow powder left behind, consisting of a combination of

—on bismuth:

—on antimony:

—on cobalt:

—on nickel.

ARSENIC.
 Action of arsenical acid on manganese.

nickel and arsenic, most probably in the acid state: the arsenic is reduced with charcoal, but the nickel is not. Calx of manganese is scarcely acted upon by acid of arsenic; but, when the manganese is partly or entirely reduced, it is dissolved in the humid way; and affords crystals as soon as the acid is nearly saturated. The regulus, digested with the arsenical acid, becomes covered with a white powder of arsenical calx. When one part of the regulus was mixed with two parts of the dry acid, and exposed to distillation, the regulus was sublimed before the heat was sufficiently great to fuse the acid, and consequently no mutual action took place; but when the acid was first fused, and the regulus added successively in small lumps, inflammation took place, and calx of arsenic was sublimed.

Combinations of regulus of arsenic.

Regulus of arsenic is soluble in unctuous oils, in a boiling heat: the solution is black, and has the consistence of salve when cold*. Most metals unite with arsenic; which most probably exists, in the reguline state, in such as possess the metallic brilliancy. The calx, more or less acidified, is common in many minerals.

Uses of arsenic.

Arsenic is used in a variety of arts. It enters into metallic combinations wherein a white colour is required. Glass manufacturers use it; but its effect in the composition of glass does not seem to be clearly

* On arsenic and its acid, consult Scheele's Essays, p. 143; Bergman's Essays, vol. ii.; Pelletier, in the Journal de Physique for 1782, &c. &c.

explained.

explained. Orpiment and realgar are used as pigments. ARSENIC.
Some attempts have been made to introduce it into
medicine; but as it is known to be a most violent
poison, it is probable that the fear of its bad effects may
long deprive society of the advantages it might afford
in this way.

C H A P. XII.

CONCERNING COBALT.

COBALT.

Characters of
cobalt.

COBALT is a semi-metal, of a whitish grey, or steel colour; hard, brittle; of a dull, close-grained fracture, and moderate specific gravity. It is rather more difficult of fusion than copper; does not easily become calcined; and its calx is of so deep a blue colour, as to appear black. The most remarkable and most valuable property of this metallic substance is, that its calx, when fused with borax, or with alkali and sand, produces a blue glass, known by the name of smalt. The action of air soon tarnishes it; but water has little or no effect upon it.

Combination
with vitriolic
acid:

Concentrated and boiling vitriolic acid, distilled nearly to dryness, combines with this semi-metal. Much vitriolic acid air flies off; and the cobalt is in part calcined, and in part converted into a crystallizable salt, soluble in water, and precipitable by lime and by alkalis in the form of a rose-coloured powder or calx. Diluted vitriolic acid acts upon the calx of cobalt, and forms the same salt.

—with nitrous
acid.

Nitrous acid dissolves cobalt by the assistance of a moderate heat. Nitrous air is disengaged; and the solution affords deliquescent crystals by evaporation, which do not detonate on ignited coals, but boil up and leave a red calx. Lime, and the alkalis, precipitate the solution; and, if the alkali be added in excess, it dissolves the precipitate.

The

The marine acid has scarcely any action on cobalt, unless it be boiling; in which case it dissolves a small portion. It dissolves the calx more readily; with which it forms a red brown fluid, that becomes green when heated. This solution affords deliquescent crystals by evaporation.

COBALT.

Combination
with marine
acid:

Aqua regia dissolves cobalt more easily than the marine, though not so readily as the nitrous, acid. This solution is well known, as one of the most celebrated sympathetic inks afforded by chemistry. If it be diluted with a sufficient quantity of water to prevent its action upon paper, and then used to write with, the letters are invisible as soon as the clear solution has become dry: but, if the paper be held to the fire for a short time, they appear of a fine green colour; which again disappears by removing it, and suffering it to cool again. If the heat be continued too long after the letters appear, it will render them permanent. This effect seems to be analogous to that which obtains in the marine solution: but none of the efficient causes of change of colour in this, or any other chemical phenomenon, have been hitherto explained.

—with aqua
regia.Sympathetic
ink.

The acid of borax does not act immediately on cobalt, in the humid way: but borax itself, added to either of the foregoing solutions, effects a decomposition by double affinity; the alkali uniting with the solvent acid, while the acid of borax seizes the cobalt, and forms a scarcely soluble compound, which falls down.

Acid of borax
and cobalt.

The acid of sugar precipitates cobalt from its solutions, in the form of a pale rose-coloured powder.

Acid of sugar.

Whether

COBALT.

Habitudes of
cobalt :

Whether alkalis or earths combine with this metal directly, by the intervention of water, has not been determined.

—with nitre :

Cobalt does not act on neutral salts in general. It detonates feebly with nitre, when projected into a red-hot crucible, with twice or thrice its weight of that salt. The metal becomes calcined by the action of the nitre ; but the changes in both substances require farther examination.

—with sal ammoniac :

Sal ammoniac is not decomposed by cobalt.

—with sulphur :

Sulphur does not unite with cobalt, but with difficulty. Liver of sulphur combines more readily with it. The action of phosphorus, or its acid, on this substance, remains to be ascertained.

—with metallic substances.

This semi-metal unites by fusion with most of the metals and semi-metals, as has before been noticed. Silver, lead, and bismuth, do not mix with it ; and zinc does not but with great difficulty.

Native cobalt
and its ores.

Cobalt is found native in alloy with arsenic and iron, and of a steel-grained appearance when broken ; or in a calciform state, of a black colour, either pulverulent or indurated : or combined with arsenical acid, in the flowers of cobalt, of a red colour ; or, lastly, united to sulphur and iron, with or without arsenic, of various shades of redness. Bismuth, nickel, and other substances, are contained in these ores. They may in general be distinguished by solution in aqua regia ; with which, after dilution with water, they form the sympathetic ink above described.

Humid analysis.

The native cobalt, and its calciform or sulphureous ores, may be examined by solution in aqua regia, and evaporation to dryness ; after which, the calcined

calcined cobalt may be dissolved by vinegar. When this calx is precipitated by mild mineral alkali, the regulus may be accounted for, by allowing one hundred grains for every hundred and sixty grains of precipitate. The other component parts of the residue, not taken up by the vinegar, may be ascertained by the methods described in the preceding chapters. The red arsenical cobalt ore, which contains arsenical acid, may be decomposed by vitriolic acid; and the disengaged arsenical acid will be taken up by highly-rectified spirit of wine; after which, the combination of vitriolic acid and cobalt may be dissolved in water, and precipitated by mild alkali: or the ore itself may be dissolved in water, sharpened by an acid; and the calx be then precipitated by the alkali.

COBALT.

Humid analysis
of cobalt ores.

In the dry way, the ores of cobalt, after previous pounding, washing, and roasting, may be fused with three times their weight of black flux, in a lined and covered crucible, by the heat of a smith's forge. The tingeing power of cobalt ores may be assayed by fusion with three parts of fixed alkali, and five of powdered flint, or glass. The alkali must be put first into the crucible; next, the flint; and, above all, the roasted ore. When cobalt ores, containing bismuth, are reduced, this semi-metal usually occupies the lower part of the crucible, and may be separated from it by a blow with a hammer; or at least by eliquation, or melting, on account of its greater fusibility.

Analysis in the
dry way.

Cobalt is found in several parts of Europe, but most plentifully in Saxony; or, at least, it is manufactured there in the greatest plenty. Chaptal assures

Cobalt found
most plentifully
in Saxony.

COBALT.

Manufacture
of zaffre and
smalt.

us, that the Saxons at present import it from the south of France, where it is afforded by the Pyrenean mountains. The ore is usually broken into pieces about the size of a hen's egg, and the stony parts picked out. The sorted mineral is then pounded in mills, and sifted through wire sieves. By washing in water, the lighter parts are carried off; and the remainder is calcined in a furnace resembling an oven, wherein it is heated by the action of the reverberated flame of wood which plays upon it. In this situation, it is occasionally stirred with long iron rakes; and emits fumes, consisting chiefly of arsenic, which is collected in a long horizontal chimney, built for that purpose. If the ore contain bismuth, this fusible semi-metal is collected at the bottom of the furnace. The cobalt, after a sufficient torrefaction, remains in the form of a dark grey calx, called zaffre. The zaffre of commerce always contains twice or thrice its weight of powdered flints. The flint is pulverized, for this and other purposes, by means of previous ignition, and quenching in water, which renders it friable. Smalt is a blue glass, composed of one part of the calcined cobalt, fused with two of the flint powder, and one of pot-ash. Powder blue, or azure, is obtained by grinding smalt in mills, and afterwards washing it in water. This last operation is performed in a cask filled with water, and pierced with three openings at different heights. The water of the uppermost cock carries out the finest blue, which they call azure of the first fire. The larger particles fall more speedily, and the azure brought out by the water of the three cocks forms the different degrees of fineness known under

under the names of azure of the first, second, and third fires. COBALT.

The use of this metallic substance is confined chiefly to the production of the blue glass for enamels, and other purposes. Powder and stone blue, used by laundresses, is a preparation made by the Dutch from the coarse smalt. Uses of cobalt.

C H A P. XIII.

CONCERNING ZINC.

ZINC.
 Characters of
 zinc.

ZINC is a semi-metal, of a blueish white colour, somewhat brighter than lead; of considerable hardness; and so malleable, as not to be broken with the hammer, though it cannot be much extended in this way. It is very easily extended by the rollers of the flattening mill. When broken by bending, its texture appears as if composed of cubical grains. On account of its imperfect malleability, it is difficult to reduce it into small parts by filing or hammering: but it may be granulated, like the malleable metals, by pouring it, when fused, into cold water; or, if it be heated nearly to melting, it is then sufficiently brittle to be pulverized. It melts long before ignition, at about the 700th degree of Fahrenheit's thermometer; and, soon after it becomes red-hot, it burns with a dazzling white flame, of a blueish or yellowish tinge, and is calcined with such rapidity, that it flies up in the form of white flowers, called the flowers of zinc, or philosophical wool. These are generated so plentifully, that the access of air is soon intercepted; and the combustion ceases, unless the matter be stirred, and a considerable heat kept up. The white calx of zinc is not so volatile, but is driven up merely by the force of the combustion. When it is again urged by a strong heat, it becomes converted into a clear yellow

glass.

glafs. If zinc be heated in clofed veffels, it riles without decomposition. Zinc appears to be the moft volatile of metallic fubftances, except the regulus of arfenic.

ZINC.

The diluted vitriolic acid affords zinc; at the fame time that the temperature of the folver is increased, and much inflammable air efcape: an undiffolved refidue is left, which confifts of plumbago. The theories of this folution, and the difengagement of inflammable air, are perfectly fimilar to thofe which have been before explained in the chapter on iron. As the combination of the vitriolic acid and the calx proceeds, the temperature diminifhes; and the vitriol of zinc, which is more foluble in hot than cold water, begins to feparate, and difturb the tranfparence of the fluid. If more water be added, the falt may be obtained in fine prifmatic four-fided cryftals. The white vitriol, or copperas, ufually fold, is cryftallized haftily, in the fame manner as loaf fugar, which, on that account, it refembles in appearance: it is flightly efflorefcent. The white calx of zinc is foluble in the vitriolic acid, and forms the fame falt as is afforded by zinc itfelf.

Solution of zinc in vitriolic acid.

White vitriol.

Diluted nitrous acid combines rapidly with zinc, and produces much heat, at the fame time that a large quantity of nitrous air flies off. The folution is very cauftic, and affords cryftals by evaporation and cooling, which flightly detonate upon hot coals, and leave a calx behind. This falt is deliquescent.

Solution of zinc in nitrous acid:

Marine acid acts very ftrongly upon zinc, and engages much inflammable air; the folution, when evaporated, does not afford cryftals.

—in marine acid.

Water

ZINC.

Water impregnated with fixed air dissolves a considerable proportion of zinc. The other acids have not been tried.

Habitudes of
zinc :

Zinc is precipitated from acids, by the soluble earths, and the alkalis: the latter redissolve the precipitate, if they be added in excess.

—with vitri-
olic salts :

Zinc decomposes, or alters, the vitriolic neutral salts in the dry way. When fused with vitriolated tartar, it converts that salt into liver of sulphur; the zinc at the same time being calcined, and partly dissolved in the hepar. In this operation, the vital air of the acid combines with the zinc, and calcines it; at the same time that, according to the ancient theory, the phlogiston of the metal combines with the acid base, and converts it into sulphur. In the new theory, the transposition of phlogiston is considered as hypothetical and unnecessary: because, the metal and the sulphur being taken to be simple substances, the vitriolic acid becomes sulphur, merely by the loss of its vital air; and the zinc becomes calcined merely by the acquisition of the same substance.

—with nitre :

When pulverised zinc is added to fused nitre, or projected together with that salt into a red-hot crucible, a very violent detonation takes place; insomuch that it is necessary for the operator to be careful in using only small quantities, lest the burning matter should be thrown about. The zinc is calcined; and part of the calx combines with the alkali, with which it forms a compound, soluble in water.

—with com-
mon salt; sal
ammoniac;
and alum.

Zinc decomposes common salt, and also sal ammoniac, by combining with the marine acid. The filings of zinc likewise decompose alum, when boiled in a solution

solution of that salt, probably by combining with its excess of acid.

ZINC.

Sulphur, though its action is almost general on metallic substances, does not combine with zinc. ^{Habitudes of zinc with sulphur :} This property affords a ready means of purifying the semi-metal, by projecting sulphur upon it, when melted in a shallow crucible. It has been a subject of remark, among chemists, that many of the zinc ores consist of this semi-metal combined with sulphur, though art has not yet discovered the means of effecting the same combination. But the difficulty is removed by the consideration, that the sulphur does not unite with zinc itself; yet it readily does with its calx, and forms a compound similar to the zinc ores, called blendes; in which, for that reason, the zinc may be presumed to exist in the calciform state.

Liver of sulphur does not combine with zinc, either —with liver of sulphur : in the humid or dry way.

Most of the metallic combinations of zinc have —with metals. been already treated of. It forms a brittle compound with antimony; and its effects on manganese, wolfram, and molybdena have not yet been ascertained.

Native zinc has been very seldom found. The ^{Native zinc and its ores.} calciform ores of zinc are the zinc spar, of a whitish grey colour, resembling a lead spar; and the impure calx called calamine, which is of a white, grey, yellow, brown, or red colour, containing iron, clay, calcareous and other earths, and lead. The ore called blende, 'mock lead, or black jack, consists of zinc mineralized with sulphur and iron: of this there are several varieties. They are in general of a plated texture; and frequently of a quadrangular

C c

form,

ZINC.

form, like galena, or potters' lead ore, though they are considerably less heavy. These ores are found in various parts of Europe; and, in considerable plenty, in the mine counties of England.

Humid analysis
of zinc and its
ores.

Native zinc may be assayed, in the humid way, by the mineral acids. When it is dissolved in these, if there be any other metal present, it may be precipitated by the addition of a known quantity of zinc. The weight of calx of zinc precipitated by mild alkali from its vitriolic solution, will amount to 193 grains for every 100 of the metal it represents. The sulphureous zinc ores must be carefully treated with nitrous acid; which will dissolve the zinc, and leave the sulphur. Extraneous metals may be precipitated, and the quantity of zinc ascertained, as before.

Essay of cala-
mines.

The essay of calamines is sometimes made by pounding and mixing them with charcoal, and then heating them in a crucible covered with a copper plate. The reduced zinc rises, and converts the copper into brass; and, in this way, some judgment may be formed of its value in the operation of brass-making. Most of the zinc, whether in the metallic state, or in the form of an impure calx, called *cadmia fornacum*, is obtained in the roasting of various kinds of ores at Ramelsburg. For this purpose, the anterior part of the furnace is kept cold by wetting it: by which means the volatilized zinc is condensed, and falls into a cavity, containing charcoal dust, which defends it from calcination.

Distillation of
zinc.

The process for obtaining zinc from its ores by distillation, which is practised in England, and said to have originally been derived from the Chinese, is performed

formed in a furnace, in the form of a circular oven; in which are placed six pots, each about four feet in height, and of a conical shape, resembling an oil jar. Into the bottom of each pot an iron tube is inserted, which passes through the floor of the furnace into a vessel of water. These pots are filled with a mixture of calamine and charcoal; and their mouths are then close stopped with clay. The fire being then properly applied, the metallic vapour of the calamine issues through the iron tube, which is the only place where it can escape. In this way it is condensed in small particles in the water; which are afterwards melted into ingots for sale, under the name of spelter*. The substance sold in London by the name of spelter, is a kind of soft brass, in a granulated form, which is used by the braziers and others for soldering.

ZINC.

Distillation of zinc.

Spelter;

The chief purpose to which zinc is applied consists in the fabrication of brass, and other gold-coloured mixtures. Its calces and salts have been occasionally employed in medicine.

Use of zinc;

* Watson's Chemical Essays, vol. iv.

CHAP. XIV.

CONCERNING ANTIMONY.

ANTIMONY.
 Characters of
 antimony.

REGULUS of antimony is of a silvery white colour; very brittle, and of a plated or scaly texture. Its specific gravity is moderate. Soon after ignition it melts; and, by a continuance of the heat, it becomes calcined, and rises in white fumes, which may afterwards be volatilized a second time, or fused into a hyacinthine glass, according to the management of the heat: they are called argentine flowers of regulus of antimony. In closed vessels, the regulus rises totally without decomposition. This metallic substance is not subject to rust by exposure to air; though its surface becomes tarnished by that means. Its calces are soluble in water; and, in that respect, resemble the calx of arsenic, probably by an approach towards the acid state.

Action of vitriolic acid on antimony.

Vitriolic acid, boiled upon the regulus of antimony, calcines the greater part, so as to render it insoluble; the acid being at the same time decomposed. Much vitriolic acid air escapes; and, towards the end, a small quantity of sulphur is sublimed. By washing the residue in water, a vitriolic salt of antimony is separated from the calx, which does not crystallize.

Nitrous acid.

Nitrous acid very readily attacks antimony in the cold. Most part of the metal is calcined by this action; but a portion is dissolved, and affords deliquescent crystals, decomposable by heat. The calx of antimony

antimony formed by this acid is very white, and difficult of reduction. ANTIMONY,

Continued digestion is required for the solution of Solution of antimony in marine acid :
 regulus of antimony in the marine acid. A considerable quantity is however at length dissolved; which affords very deliquescent crystals. This salt melts by the application of heat; and is decomposed by distilled water, in the same manner as the butter of antimony, from which it does not much differ.

Dephlogisticated or aerated marine acid dissolves the regulus of antimony with great facility. —in dephlogisticated or aerated marine acid:

Aqua regia, composed of seven parts nitrous, and one marine acid, dissolves it very readily; but lets fall a portion of white calx as it cools. The solvent power of either of the three ancient mineral acids on this semimetal; appears to be increased by mixture with any one of the others. —in aqua regia.

Earthy substances do not act on the regulus of antimony in the dry way. Its calx, however, enters readily into the composition of glass; to which it imparts more or less of an hyacinthine colour. When fused with vitriolated tartar, it converts it partly into hepar, or liver of sulphur; which dissolves a portion of the calx of antimony: that is to say, the vital air of the acid calcines the regulus of antimony, while part of the acid becomes converted into sulphur; either simply by the loss of its vital air, or else by that loss, together with the acquisition of phlogiston from the regulus. Habitude of regulus of antimony with earths :
—with vitriolated tartar.

Nitre detonates very readily with the regulus of antimony: when equal parts of these substances are projected into a red-hot crucible, the residue of calx and alkali is known by the name of diaphoretic antimony. Detonation with nitre.

ANTIMONY. mony. When the saline part is washed out by hot water, the residue is called washed diaphoretic antimony. The water used in the washing contains a portion of the calx, suspended by the alkali. This may be precipitated by the addition of an acid, and has been distinguished by the name of ceruse of antimony.

Distillation of regulus of antimony with corrosive sublimate. When regulus of antimony is pulverized, and accurately mixed with about twice its weight of corrosive sublimate, a mutual action takes place with the production of heat; and, if the mixture be distilled with a gentle fire, a thick fluid comes over, which congeals in the receiver, or in the neck of the retort, and is called butter of antimony. The residue consists of revived mercury, and some regulus and calx of antimony.

Theory. In this experiment, the dephlogisticated marine acid combines with the antimony, while the mercury is revived; as may be easily explained on either of the two theories of chemistry. If the combination of regulus of antimony and sulphur be used instead of the regulus itself, the mercury will be obtained in the form of cinnabar, at a much greater heat than is required to sublime the butter of antimony.

Powder of algaroth. When butter of antimony is thrown into pure water, an abundant white precipitate, or calx, falls down, which is a violent emetic, and is known by the name of powder of algaroth.

Bezoar mineral. Nitrous acid dissolves the butter of antimony. The solution, which does not appear to differ greatly from the solution of the regulus in aqua regia, soon deposits a portion of calx. When an equal weight of nitrous

nitrous acid has been three times distilled to dryness **ANTIMONY.**
 from butter of antimony, the residue, after ignition,
 is called bezoar mineral; and seems to be little more
 than a calx of the metal.

Sulphur combines very readily with the regulus of Combination
of regulus of
antimony with
sulphur :
 antimony, and forms a substance differing in no re-
 spect from the mineral, or ore, to which the name
 of antimony is exclusively appropriated. One part of
 sulphur completely mineralizes four of the regulus.

Liver of sulphur dissolves the regulus of antimony, —with liver of
sulphur.
 and affords an orange-coloured precipitate upon the
 addition of an acid.

Antimony, or the regulus combined with sulphur, Crude anti-
mony :
 was a favourite object of research in the experiments
 of the alchemists; in consequence of which, its pro-
 perties are much better known than those of the pure
 regulus. If this substance be heated, it melts, and —its habitues:
 a considerable portion of the sulphur flies off, at the
 same time that the regulus becomes calcined, and
 rises in white vapours. A gentler heat, less than is —by heat :
 necessary to fuse it, converts it into a grey calx: this
 calx contains a portion of sulphur. If it be urged by
 a stronger heat, it melts into the form of glass, which
 is more or less transparent, according to the degree of
 calcination of the metal, and the dissipation of the
 sulphur. When it contains much sulphur, the glass
 is fusible, opaque, and of a dark red colour; whence it
 has been called liver of antimony.

When acids are applied to crude antimony, they —with acids.
 dissolve the regulus, and leave the sulphur. The ni-
 trous acid is best adapted to this solution.

ANTIMONY. Diaphoretic antimony is most commonly and advantageously prepared by detonating the crude antimony with nitre instead of the regulus; the only difference being, that more nitre is required for the detonation; and that the residue contains vitriolated tartar, as well as alkali and calx.

Diaphoretic
antimony.

Antimonial
medicines.

There are several preparations, consisting of combinations of antimony with an alkali, in which the proportions of the ingredients, and the state of the calx, are very different, according to the nature and management of the processes. Many of these have been highly praised in medicine; at the same time that they have been as strongly exclaimed against for their ill effects. Both these assertions appear to have been well founded. It is sufficiently proved that antimonial medicines have produced the happiest effects, and are justly entitled to be considered as very powerful remedies; but, on the other hand, it is equally certain, that their great efficacy must have required greater attention, in their first exhibition, than perhaps may have been paid; and the complicated nature of many of the processes must have rendered it very difficult to produce substances possessing exactly the same properties, or proportion of component parts, at all times.

Kermes mineral.

If antimony be treated with a fixed alkali, either by fusion and subsequent solution in boiling water, or by simple ebullition, a precipitate is afforded by cooling, which is called kermes mineral, formerly used in medicine. It is thought to consist of the calx of antimony, in combination with a portion of sulphur; but its com-

component parts have not been accurately determined, ^{ANTIMONY,} and its properties differ according to the various methods used in preparing it.

The antimonial preparations most commonly used at present are, antimonial wine, and emetic tartar. ^{Antimonial medicines.} These, like every other preparation of this semi-metal, are prepared in a variety of ways. The wine may ^{Emetic wine.} be had by infusing pulverized glass of antimony in Spanish white wine for some days, and then filtering the clear fluid through paper. A very minute portion of the calx is taken up; and this is greater or less, according as the wine is more or less acid; and, perhaps, according to the temperature of the weather at the time of administering it. On this account, it is found necessary to give this medicine cautiously, and by small portions at a time, when it is intended that it shall act as an emetic. The emetic or anti-^{Antimonial tartar.} moniated tartar of the London College is thus prepared:—Take of crude antimony and nitre equal parts, separately reduced to powder; mix them, and inject them into a crucible heated to whiteness, that the mixture may melt after deflagration; pour it out, and reserve the yellow mass beneath the scorix, under the name of crocus of antimony; reduce this to a very subtile powder; boil it in water, and wash the powder repeatedly in warm water, till it becomes perfectly insipid: then take equal parts, by weight, of the washed crocus of antimony and of crystals of tartar, and boil them together, in three pints of water for every pound of the mixture, during half an hour: filter the liquor; and, after due evaporation, set it by to crystallize.—This is the antimonial tartar.

ANTIMONY. tartar. It is a triple salt, consisting of the acid of tartar, united to vegetable alkali, and antimony partially calcined; and is considered as a safe medicine, whose properties and effects are more constant, and milder, than most other antimonial remedies.

Medical effects
of antimony.

It has not been clearly determined on what circumstances the medical effects of antimony depend. The saline preparations of mercury, and other metals, are supposed to derive their causticity from their tendency to become reduced to the metallic state; in consequence of which, they corrode and decompose other combustible substances: but whether this be the case with antimony, is doubtful. It appears necessary, however, that antimony should be in the saline state, in order that it may act upon the animal system. When the regulus is made into those small balls or pills, which, on account of the little change they undergo in passing through the human body, have been called per-

Perpetual pills.

petual pills, its purgative action is more or less violent, according to the quantity of acid it meets with; and, in the preparations of this semi-metal, their effects seem likewise to be governed by the same circumstance joined to their respective degrees of solubility. The nearly pure and insoluble calx, produced by detonation with a large proportion of nitre, is almost ineffectual; whereas the more soluble calces or combinations are more or less active, according to their respective nature. Hence it appears to follow, that the simplest saline combinations are the most likely to produce effects constantly similar; and that most of the calces and combinations, so highly extolled in the earlier age of chemistry, are attended with dangerous uncertainty in their operation.

Antimony

Antimony combines with most other metallic substances, and produces mixtures whose properties have been attended to under their respective titles. ANTIMONY.

Antimony is found either native, in masses of the regulus, composed of shining irregular plates; or calciform, in white crystallized filaments; or combined with sulphur, in the dark blueish or grey friable mineral, called antimony, consisting most commonly of brilliant filaments disposed parallel to each other; or, lastly, combined with sulphur and arsenic, in an ore which greatly resembles the foregoing, except that it is of a red or reddish colour. Native antimony and its regulus.

Native regulus of antimony, or its calx, may be assayed by nitrous acid, which dissolves whatever arsenic it may contain, and only calcines the antimony. The sulphureous antimonial ores are most conveniently analysed by aqua regia, which takes up the calx, and leaves the sulphur, which may be separated by filtration. The remaining solvent may be examined with the usual precipitants. In the dry way, antimony is separated from its stony parts by fusion in a moderate heat, nearly in the same manner as bismuth; and may be reduced, by slowly roasting it, till it becomes converted into a grey calx, which may be briskly fused with twice its weight of black flux. Humid analysis. Dry way.

Antimony and its regulus are chiefly used in medicine, and in some metallic alloys, such as that used for printers types, small shot, &c. Uses.

C H A P. XV.

CONCERNING MANGANESE.

MANGANESE.

Characters of
manganese.

THE regulus of manganese is a semi-metal of a dull whitish colour when broken, but soon grows dark by calcination from the action of the air. It is hard, brittle, though not pulverable, and rough in its fracture; so difficultly fusible, that no heat yet exhibited has caused it to run into masses of any considerable magnitude; and appears to be more disposed to calcination than any other metallic substance, unless we may except wolfram. Its calces are white when imperfect; but black, or dark green, when perfect: the white are soluble in acids. When broken in pieces, it falls into a powder by spontaneous calcination; and this powder is magnetic, though the masses were not possessed of that property. It seems as if the regulus of manganese were capable of depriving a small proportion of iron of its magnetism; but that the effect ceases as soon as that regulus is converted into calx. A strong heat expels vital air from the calx of manganese.

Concentrated vitriolic acid attacks the regulus of manganese, but much more readily when diluted with two or three times its weight of water; at the same time that inflammable air is disengaged. A black spongy substance remains undissolved, which has not been examined. The solution is colourless, and affords
crystals

crystals by evaporation. Mild alkalis precipitate a MANGANESE, white calx, soluble in acids; but pure alkalis afford a brown calx, which soon grows black in the air, and is scarcely soluble. The black calx of manganese, when Black calx of manganese. old, or well made, is altogether insoluble in acids, unless some combustible substance be added. It appears therefore that the metal in this state is too far calcined, and requires to be reduced again in a certain degree towards the metallic state, to be dissolved. If vitriolic acid be added, and drawn off by distillation several times from the black calx, by an heat nearly approaching to ignition, in a glass vessel; it is found that vital air is disengaged towards the end of each process, and part of the calx is dissolved. The solution of the calx in acids, by the addition of combustible matter, is easily accounted for, on either of the theories of chemistry, by affirming that the reduction is effected by the addition of phlogiston, or the subtraction of vital air from the calx by means of the combustible substance. The phlogistic theory appears however to be deficient, in explaining the solution by mere vitriolic acid, at an elevated temperature *, on account of the absence of phlogiston; but the new theory simply asserts the facts, that the calx loses vital air in consequence of the elevated temperature, and is rendered soluble in the acid.

Theory.

* Bergman, ii. 215 (on the hypothesis, that heat is matter; that this matter consists of pure air united to phlogiston; and that manganese decomposes the heat), derives the phlogiston required for the solution, as well as the vital air which flies off, from this decomposition. These positions did not appear sufficiently grounded to enter the text.

Nitrous

MANGANESE.

Solution of re-
gulus of man-
ganese in ni-
trous acid :

Nitrous acid dissolves the regulus of manganese with effervescence, and the escape of nitrous air. A spongy, black, and friable matter remains, whose properties resemble molybdena. The solution does not afford crystals. The perfect calx is not soluble in pale nitrous acid, unless some combustible matter be added.

—in marine
acid.

The regulus is dissolved in the usual manner by marine acid. The black calx is likewise soluble; but adheres so weakly to the acid, as to be separated even by the mere addition of water: but, if this solution be exposed to a digesting heat for some hours, an intestine motion, like an effervescence, takes place; the smell of dephlogisticated or aerated acid is perceived; and the combination becomes more perfect, so as not to afford a precipitate, unless an alkali be added. Marine acid dissolves the black calx also, by the addition of a combustible substance. Mercury, and even gold, will effect this combination. The solution of manganese in marine acid scarcely affords crystals, but a deliquescent saline mass by evaporation, which is soluble in ardent spirit.

Explanation.

In the permanent solution of black calx of manganese by marine acid, it is seen that the acid itself must communicate the property to the calx, on which its solubility depends; that is to say, it must either afford phlogiston, or absorb vital air: and accordingly, the red vapours which escape are distinguished by the name of dephlogisticated, or aerated, marine acid, according to the theory which may be adopted by the speaker.

Other

Other acids likewise dissolve this metallic substance. MANGANESE.
 The fluor acid, and also the phosphoric acid, form compounds of difficult solubility, which envelop and defend it from their farther action in a short time.

In the dry way, the calx of manganese combines with such earths and saline substances as are capable of undergoing fusion in a strong heat. These experiments are most advantageously performed by the blow-pipe, on small quantities of matter; because, in this way, the whole of the phenomena are clearly seen. The most remarkable property of the solutions is, that a due proportion of combustible matter renders them colourless; for which reason, the calx of manganese is used by the glass manufacturers to destroy the colours of glass. If a globule of microcosmic salt be fused by the blow-pipe upon charcoal, and a small portion of the black calx of manganese be added, the colour will be of a blueish red; or of a deep red, if the quantity of calx be greater. If the fusion be continued by the interior blue flame, the colour at length disappears; but may be easily revived again, by softening the globule with the exterior flame. Combinations of calx of manganese in the dry way.
 A small particle of nitre instantly restores the red colour; but inflammable matter, or vitriolic salts, contribute to discharge it. If the globule, after being deprived of all colour, be fused in the silver spoon, it recovers its redness; and the colour is not discharged by any management of the fusion, unless some inflammable matter be added. Changes of colour.

These remarkable changes of colour, which may be repeatedly produced, depend evidently on the presence or absence of combustible matter; or, which amounts

Explanation.

to

MANGANESE. to the same thing, on the degree of calcination of the
 Explanation of the changes of colour in glasses which contain manganese.

manganese which is held in solution. When the highly calcined or black manganese is first added, it produces a coloured globule; if inflammable matter be added, the calx is partly reduced, and forms a colourless combination. Nitre restores the colour by its well-known property of calcining metals. When the fusion is performed by the interior flame, the globule may be considered as if heated in a close vessel, in contact with charcoal; because the surrounding flame prevents the access of air: a revival of the calx therefore ensues, and the colour vanishes. But when the external flame is used, its apex, or point only, touches the globule; and the surrounding air promotes or maintains the calcination more effectually than the charcoal can produce the contrary effect: the consequence therefore is, that the colour again appears. Vitriolic salts seem to forward the action of the charcoal, which converts them into sulphur; and the colour remains fixed in the spoon, because there is no combustible substance present, which is sufficiently so to promote the revival of the calx. It is evident that both the theories of chemistry are applicable to these facts, whether the charcoal revives the calx by phlogisticating it, or by depriving it of its vital air; or whether the calcination by the apex of the flame be effected by the dissipation of phlogiston, or by the absorption of vital air from the atmosphere.

Theories.

Nearly similar changes are produced when the calx is fused with borax, or an alkali.

Combination with sulphur.

Regulus of manganese does not appear to combine with sulphur; but eight parts of the calx combine with

with three of sulphur, and produce a yellowish green ^{MANGANESE.} mass, which is acted upon by acids; the metal being dissolved with effervescence, and the disengagement of hepatic air. The remaining sulphur may be collected on a filter.

This semi-metal melts readily with most of the other metals, but rejects mercury. Gold and iron are rendered more fusible by a due addition of manganese; and the latter metal is rendered more ductile. Copper becomes less fusible, and is rendered whiter, but of a colour subject to tarnish *.

Metallic combinations of manganese.

Regulus of manganese has been found native among the powdery or calciform ore of this metallic substance. Its properties, in this state, perfectly resemble the regulus produced by art: Manganese appears to exist in the calcined state in all its ores; though contaminated with admixtures of earths, or other metallic matters. They are, white, red, brown, or black; either pulverulent, indurated, or crystallized. Vegetable ashes likewise afford indications of manganese.

Native manganese and its ores.

To analyse the ores of manganese in the humid way, they must be reduced to a subtile powder, and immersed in a mineral acid, with a piece of sugar to assist the solution. If nitrous acid be repeatedly abstracted to ignition from the ore, the iron it contains will be rendered nearly insoluble from calcination; and the manganese may be taken up by strong concentrated vinegar, or diluted nitrous acid. This, when precipitated by mild mineral alkali, affords 180

Humid analysis.

* Annales de Chimie, i. 303.

MANGANESE. grains of precipitate for every 100 grains of regulus: or if the metals be precipitated from superabundant nitrous acid, by Prussian alkali, the manganese will be totally dissolved by pure water, while the iron remains behind.

Spontaneous
inflammation
of black wadd.

The ore of manganese, which is known in Derbyshire by the name of black wadd, is remarkable for its spontaneous inflammation with oil. It is of a dark brown colour, of a friable earthy appearance, partly in powder, and partly in lumps. If half a pound of this be dried before a fire, and afterwards suffered to cool for about an hour; and it be then loosely mixed or kneaded with two ounces of linseed oil; the whole, in something more than half an hour, becomes gradually hot, and at length bursts into flame. This effect wants explanation. It seems, in some measure, to resemble the inflammation of oils by the nitrous acid.

Reduction of
manganese.

The presence of manganese may be ascertained in the dry way, by the blow-pipe, from the singular changes of colour already described, when fused with microcosmic salt, or borax. The reduction of the ore is effected by mixing it with pitch, making it into a ball, and putting it into a crucible lined with powdered charcoal, one tenth of an inch thick at the sides, and one quarter of an inch thick at the bottom; then filling the empty spaces with powdered charcoal, and luting on a cover. This must be exposed to the strongest heat of a forge, or furnace, for an hour, or more. As the calx of manganese is strongly disposed to vitrification, fluxes rather impede than forward the reduction. The reduced globules of manganese

ganese are usually enveloped with a vitrified crust, **MANGANESE.** which either partly or completely defends them from ^{Speedy calcination.} the action of the air; but, when they are broken, they lose their metallic brilliancy and consistence in a very short space of time.

Manganese has hitherto been used chiefly by glass-makers and potters; but the important discoveries of the uses of dephlogisticated or aerated marine acid will, no doubt, extend its utility to several other manufactories *.

* On manganese, consult Scheele, 67—142; Bergman, ii. 201—225; the Memoirs of Pelletier, Berthollet, &c.; and the Abstracts by Elementary Writers on Mineralogy.

CHAP. XVI.

CONCERNING WOLFRAM.

WOLFRAM.

TUNGSTEN and wolfram have already been treated of in the section on acids; and the combinations of metals with the regulus of wolfram have been occasionally mentioned under their respective heads. Little else remains therefore to be said of this metallic substance, than to specify its general characters.

Characters and
habitudes of
the calx and
regulus of wol-
fram.

The yellow matter, or calx of wolfram, turns blue by exposure to light; and more intensely, if to the light of the sun. By a strong heat in a covered crucible, it becomes of a blueish black colour, with loss of weight; which it recovers, together with its original yellow colour, by calcination with access of air. These changes to the blue colour appear therefore to be partial reductions*. One hundred grains of the yellow calx, or acid, being put into a crucible with charcoal powder, well covered, and exposed to a strong heat, became converted into a button of a dark brown colour, and friable, with a diminution of forty grains of the original weight. Its specific gravity was 17.6; and, upon examination with a glass, a congeries of metallic globules was seen, some of them of the size of a pin's head; which, when broke, exhibited a fracture resembling steel. Part of this mass

* De Luyarts on Wolfram, page 58.

being

being calcined, became yellow as at first, and gained twenty-four per cent. in weight. It was not soluble in vitriolic or marine acid; but the nitrous acid, and aqua regia, converted it again into the yellow calx. The yellow calx itself could not be vitrified. Acetous acid converted the yellow colour to a blue.

WOLFRAM.

Habitudes :

When equal parts of sulphur and the yellow calx —with sulphur. were urged by a strong heat, a blue friable mass remained, weighing less than one-fourth of the whole.

CHAP. XVII.

CONCERNING MOLYBDENA.

MOLYBDENA.
 Characters of
 regulus of mo-
 lybdena.

MOLYBDENA, like manganese and wolfram, has not been reduced into masses of any considerable magnitude; but has been obtained only in small separate globules, in a blackish brilliant mass. It has been revived by a process similar to that by which regulus of manganese is obtained; but it requires a most extreme degree of heat for that purpose. The globules are grey, brittle, and extremely infusible. By heat it is converted into a white calx, which rises in brilliant needle-formed flowers, like those of antimony. Nitrous acid readily calcines and acidifies the regulus. Nitre detonates with it, and the remaining alkali combines with its calx.

Habitudes with
 various sub-
 stances.
 See also p. 221.

Detonation with nitre decomposes the native molybdena; but solution in nitrous acid is the readiest way to procure the acid of this substance. Prussian alkali, and also infusion of galls, precipitate the acid from its solutions. When acid of arsenic is heated with molybdena, it converts part of the sulphur into volatile vitriolic acid; which comes over, and combines with another portion, with which it rises in the form of orpiment. No other acids but the nitrous and arsenical have any action on crude molybdena.

The

The regulus of molybdena unites with several of the **MOLYBDENA.** metals, and forms brittle or friable compounds.

This mineral is scarce. It is distinguishable from black lead by its more shining scaly appearance, and marks paper with a more brilliant stroke ; and, as it resembles no other substance, it does not require to be assayed. Distinctive
characters.

C H A P. XVIII.

CONCERNING URANITE, OR, URANIUM.

METALLIC
SUBSTANCES.

Uranite, or
uranium.

THE celebrated professor Klaproth has detected a new metallic substance in the mineral usually distinguished by the name of pech-blende, or pitch-blende, and ranged among the ores of zinc. As it is not reducible but with the most extreme difficulty, and then only into minute grains, it appears of little consequence to enter into any formal description of its metallic state: for which reason, I shall follow the order of the professor's analysis in the present chapter*.

Description of
pitch-blende.

The pitch-blende, or ore of uranite, is found in masses, or else stratified with other earths or minerals, in the Swedish and Saxon mines. It consists of two varieties: the first in masses of a blackish colour, inclining to a deep steel grey, of little brilliancy; its fracture is unequal and concave in the smallest parts. It is perfectly opaque, considerably hard, and becomes convertible into a black powder by trituration. Its mean specific gravity is about 7.5. The second variety is usually found in strata, and is distinguished from the former by a deeper black colour, intermixed with spots of red; its colour is more shining, and

* Journal de Physique, April 1790.

approaches

approaches that of coal; it is less hard, and, when pulverized, it has a greenish tinge. METALLIC
SUBSTANCES.

This mineral suffers no change before the blow-pipe. Habitudes by
fire.
With mineral alkali it affords a a spongy, semi-opake, grey globule. With microcosmic salt it melts, and affords a green transparent globule; and in both there are sometimes seen small globules of reduced lead. When the mineral is heated alone, in a proper vessel, it gives out sulphureous acid and sulphur, with loss of weight; but if it be afterwards kept ignited for a considerable time beneath a muffle, it gains some weight by calcination.

The vitriolic acid acts very imperfectly upon pitch- Action of acids
on pitch-blende.
blende; but nitrous acid completely decomposes it, holding most part in solution, while a small proportion of sulphur, and some siliceous earth, fall down. Marine acid acts but imperfectly upon it; but aqua regia dissolves it, as well as the pure nitrous acid. This solution, after it had deposited a small quantity of corneous lead, afforded large transparent crystals by repose in the cold, which were of a faint yellowish green colour, and of a figure not easy to be ascertained.

It was remarkable, that this substance was not pre- Precipitates.
cipitable from its solvents either by iron or zinc; but volatile liver of sulphur threw down a brownish yellow precipitate. Nut-galls did not precipitate any thing, unless the superabundant acid were neutralized by an alkali; and, in this case, the precipitate by galls was of a chocolate brown.

A distinctive criterion of this metallic substance was, Precipitates.
its brownish red colour when separated by Prussian
alkali;

**METALLIC
SUBSTANCES.**

alkali; a circumstance indeed common also to copper: but this last metal falls down in flocks, whereas the former is uniformly separated through the whole fluid. Volatile alkali usually precipitates it of a yellow colour, more or less obscure, according to the purity of the mineral, or of the alkali. The two fixed alkalis, when pure, precipitate it completely in the form of a lemon-coloured calx. Mild alkalis afford a paler calx.

**Yellow calx of
pitch-blende.**

The yellow precipitate is very soluble in acids, and affords crystals by combination with the vitriolic and acetic acids. Phosphoric acid affords yellowish irregular flocks, sparingly soluble in water. Alkalis do not dissolve the yellow matter either in the dry or humid way.

Reduction.

Various attempts were made by the discoverer to revive it to the reguline state. He triturated it with linseed oil to the consistence of a paste, burned the oil in a roasting test, then placed the remaining black powder in a crucible lined with charcoal, and well covered, and exposed it to a violent heat; which operated a reduction of manganese in another crucible, but produced no other change in the calx of uranite than to render it soluble in nitrous acid, with effervescence, heat, and escape of nitrous air. This altered calx was then put into an assayer's test, covered with borax, and mixed with charcoal, and the lid luted on. The heat of a porcelain furnace reduced it into a coherent mass, consisting of very small metallic globules agglutinated together.

B O O K II.

PARTICULAR CHEMISTRY.

SECTION IV.

OF MINERAL COMBUSTIBLE BODIES, AND THE DIAMOND.

C H A P. I.

OF MINERAL COMBUSTIBLE BODIES.

THE inflammable substances found in the mineral kingdom are—1. Inflammable air, called fire-damp in the mines. 2. Hepatic air, which abounds in many hot baths, in mines, and in the neighbourhood of volcanos. 3. Naptha; a fine, thin, fragrant, colourless oil, which issues out of white, yellow, or black clays in Persia and Media. This is highly inflammable, and is not decomposed by distillation. It dissolves resins, and the essential oils of thyme and lavender; but is not itself soluble either in spirit of wine

MINERAL
COMBUSTI-
BLES.

Enumeration.

MINERAL
COMBUSTI-
BLES.

Petroleum.

Barbadoes tar.

Asphaltum.

Mineral tallow.

Jet.

Pit coal.

Peat.

wine or æther. It is the lightest of all the dense fluids; its specific gravity being 0.708. 4. Petroleum, which is a yellow, reddish, brown, greenish, or blackish oil, found dropping from rocks, or issuing from the earth, in the duchy of Modena, and in various other parts of Europe and Asia. This likewise is insoluble in spirit of wine; and seems to consist of naptha, thickened by exposure to the atmosphere. It contains a portion of the acid of amber. 5. Barbadoes tar, which is a viscid, brown, or black inflammable substance, insoluble in spirit of wine, and containing the acid of amber. This appears to be the mineral oil in its third stage of alteration. 6. Asphaltum is a smooth, hard, brittle, inflammable substance, which melts easily, and burns without leaving any ashes, if it be pure. It is slightly and partially acted on by spirit of wine and æther. 7. Mineral tallow, which is a white substance, of the consistence of tallow, and as greasy, though more brittle. It was found in the sea on the coasts of Finland, in the year 1736; and is also met with in some rocky parts of Persia. It is near one-fifth lighter than tallow; burns with a blue flame, and a smell of grease, leaving a black viscid matter behind, which is more difficultly consumed. 8. Jet, which is much harder than asphaltum; susceptible of a good polish, and glassy in its fracture. It is highly electrical, fusible in a moderate heat, and insoluble in spirit of wine. 9. Pit coal. Of this there are many varieties: they appear to consist of petroleum, consolidated with an earth, chiefly of the argillaceous kind. 10. Peat is a black inflammable earth, which is of a viscid consist-

ence

ence when fresh, but hardens by exposure to the air.

11. Turf consists of mould, interwoven with the roots of vegetables. 12. Amber has been already treated of (204). It is insoluble in water, and in spirit of wine; and no other acid but the vitriolic dissolves it.

By distillation it affords a small portion of water, an oil of the nature of petroleum, and a peculiar acid.

13. Sulphur is very abundant in the mineral kingdom. It has before passed under our observation, on account of its affording the vitriolic acid by combustion.

14. Plumbago, or black lead.

MINERAL
COMBUSTI-
BLES.

Turf. Amber.

Sulphur.

Plumbago.

When we attend to the inflammable substances found in the earth, or in the mineral kingdom, we may perceive that very few, and most probably none of them, can be truly said to belong to it; but have been elaborated in the bodies of animals or vegetables. From the turf that is pared from the surface of the earth, and owes its inflammability to the roots of vegetables which are mixed with it, we may descend to the peat, or black earth, of the moors; in many specimens of which, vegetable remains are still perceptible; though in most they appear to be deprived of every appearance of their organic texture, their oily and inflammable nature only remaining: and from thence the transition to pit-coal is easy. For if we reflect on the vast revolutions which the earth has certainly undergone through a long course of ages, by means of which its surface has been broken, displaced, and inverted, from the actions of floods, earthquakes, and the great convulsions of nature caused by volcanic eruptions, it will be no improbable inference, that the thin, though extensive, strata of pit coal, as well as the

General observations on the combustible substances found in the mineral kingdom.

**MINERAL
COMBUSTI-
BLES.**

General obser-
vations on the
combustible
matter found
in the mineral
kingdom.

the exsudations of naphtha, petroleum, and their modifications, have all arisen from the burying of extensive woody tracts of the surface, such as are common in all uncultivated countries. And this probability will be reduced to a certainty, when we advert to the natural history of pit coal, which is met with in all the various states of transformation. Whole trees are converted into pit coal, in such quantities together as to exhibit entire forests; in which the roots, trunks, branches, bark, and even species, are discernible. Coal-pits and slate-quarries exhibit innumerable marks of impressions of leaves, and other indications of their vegetable origin; and the analysis of this combustible substance tends still further to confirm this truth. On the other hand, if we attend to such inferences as chemical theory might point out from the facts around us, we shall see how small the probability is, that the mineral kingdom should, after a certain limited time, contain inflammable bodies, if they were not occasionally thrown into it, in consequence of the operations carried on within organized substances. For all inflammable substances, tending to decompose the vital air of the atmosphere, would, in process of time, revert to the class of unflammable bodies, if the operation of organized bodies, particularly of the vegetable kind, did not tend to disengage the vital air again, and render bodies combustible, which were not so when they became parts of those substances.

CHAP. II.

CONCERNING THE DIAMOND.

THE diamond is a mineral which, on several ac- DIAMOND.
 counts, appears worthy to compose an order by Characters, &c.
 itself. It is found in a sandy earth in the hither of the diamond.
 peninsula of India, in the island of Borneo, and in the
 Brazils. The form of the diamond, when perfect, is
 that of an eight-sided prism. There are also cubical
 diamonds, which are suspected to be of a different na-
 ture from the others. Diamonds are of a lamellated
 texture; and may be easily split by a blow in a proper
 direction. The consent of mankind has fixed an
 immense value upon this stone*. The inimitable
 qualities to which this preference is attached, are its
 hardness,

* The value of diamonds is reckoned by weight, at so much the
 carat. The carat used in this valuation is divided into four parts,
 called grains; but less than troy grains by one fifth: for 150 carats
 are equal to the troy ounce of 480 grains. Rough diamonds, with-
 out any flaw or blemish, are valued at two pounds sterling the single
 carat; and the expence of cutting amounts to $3\frac{1}{2}$ pounds the carat.
 The value is greatly diminished if the diamond be imperfect, or of
 a bad figure; and it increases rapidly with the size. To find the
 worth of a rough diamond, its weight in carats must be squared,
 and multiplied by two, and the product will be pounds sterling.
 A cut or finished diamond is worth four times as much as one that
 is still rough. Those of the greatest brilliancy are sometimes valued
 at a higher rate; but this value has never been applied to stones
 of

DIAMOND. hardness, which is such that it easily cuts all other substances, and takes a most exquisite and lasting polish; and its very great refracting power, which is such as to occasion all the light to be reflected which falls on any of its interior surfaces at a greater angle of incidence than $24\frac{1}{4}$ degrees. Hence its lustre, when cut into the form of a regular solid, is very great. This may be easily understood, when it is considered that an artificial gem of glass does not reflect the light from its hinder surface, until that surface is inclined in an angle of 41 degrees. The diamond therefore will not only throw back all the light which an artificial gem would reflect, but likewise one half as much more; which, falling between the angles of 41 deg. and $24\frac{1}{4}$, would have been suffered to pass through by the false gem. It is not surprising therefore that the effect of the diamond should be so much greater; more especially when we attend to its extreme transparency, and the accuracy of its polish.

—soluble in
vitriolic acid :

—combustible.

No solvent but the vitriolic acid has any effect on this gem; in which if diamond powder be triturated, and evaporation carried on nearly to dryness, the acid grows black, and deposits pellicles that burn, and are entirely consumed. In a heat somewhat greater than is required to melt silver, the diamond is entirely volatilized, and consumed with a slight flame; diminishing common air, and leaving a foot behind.

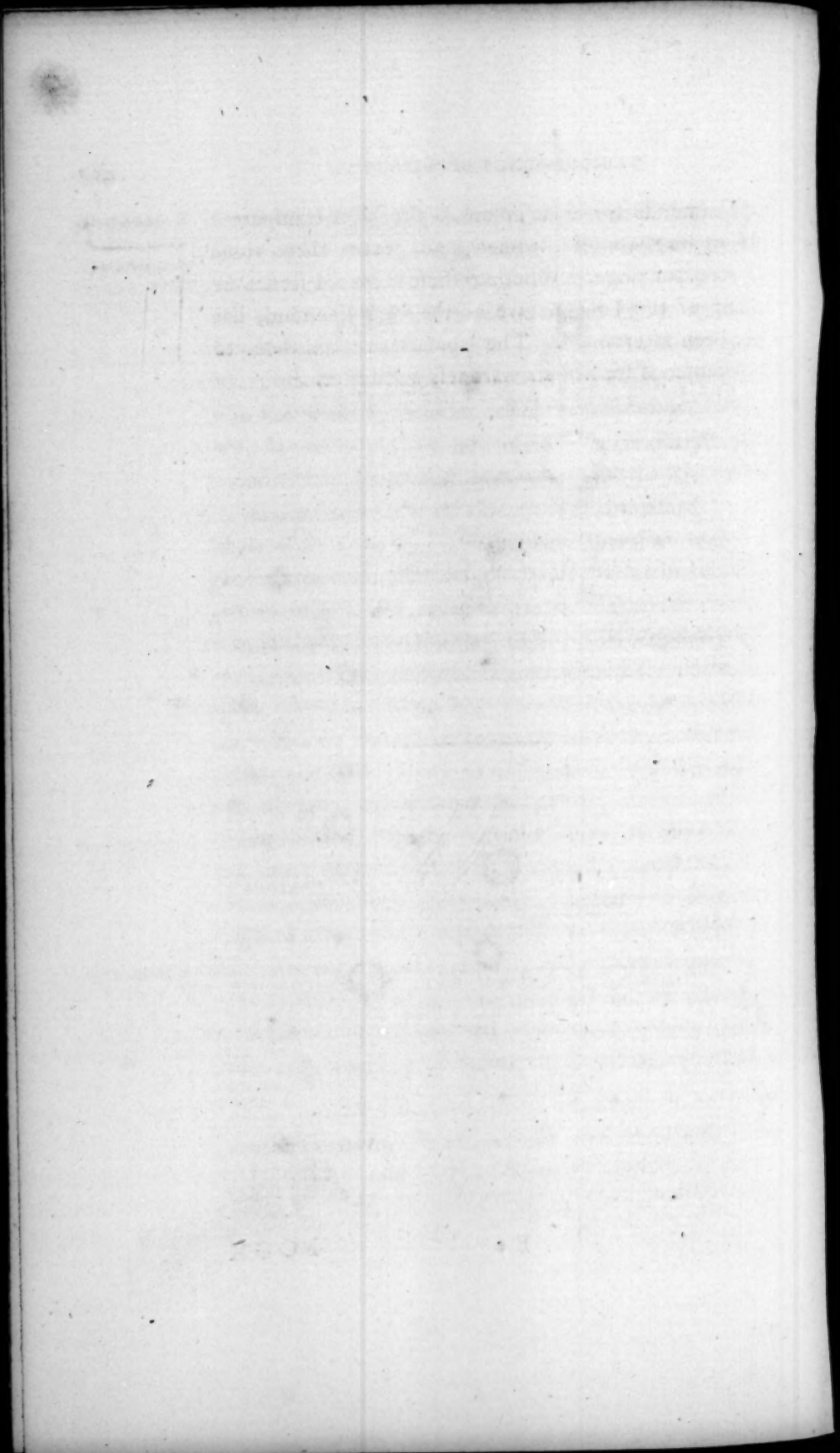
of excessive magnitude. It does not appear that any sum exceeding one hundred and fifty thousand pounds has been given for a diamond.

See Magellan's improved edition of Cronstedt's Mineralogy, for a considerable mass of entertaining information on this subject.

Diamonds

Diamonds are of all colours: the clear transparent stones are the most esteemed; and, next to them, those of a deeper tinge. Whether these coloured stones be really of the same nature as the clear diamond, has not been ascertained. The lapidaries reckon them to be diamonds from their hardness and lustre.

DIAMONDS.
Coloured diamonds.



B O O K II.

PARTICULAR CHEMISTRY.

S E C T I O N V.

CONCERNING THE PRODUCTS OF THE
VEGETABLE KINGDOM.

C H A P. I.

OF THE STRUCTURE AND COMPONENT PARTS OF
ORGANIZED SUBSTANCES.

A VARIETY of changes takes place among the ORGANIZED
great mass of minerals which come under our SUBSTANCES.
observation near the surface of the earth. These, ^{General obser-} variations.
considered individually, appear to be effected chiefly
by virtue of the chemical attractions or affinities, assist-
ed by those variations of position and of temperature
which arise from external causes; such as the solar
light, or the alterations which the capacities of other
bodies undergo. But in vegetables and animals there

ORGANIZED SUBSTANCES. is an express organization of parts, which evidently appears to have been designed by the Supreme Intelli-

The parts of organized bodies constitute apparatus for performing chemical operations.

gence for the purpose of uniting the powers of mechanism to those of chemistry. It does not immediately coincide with our present intention, to take any notice of such effects as are produced by the muscular exertion of animals, or any part of their structure, except so far as they modify the chemical processes carried on within them. In this point of view, we may consider the solid or consistent parts of vegetables and animals as composing an apparatus for performing a number of chemical processes with the fluids that circulate through them. It is true indeed that this whole series of operations is, for the most part, performed with such a minute set of vessels; at the same time that the bodies applied to each other, to exercise their respective chemical attractions, seem in general to be reduced so near their first principles; that in the present state of our knowledge we can scarcely proceed farther than to assert, that the effects are really produced by an application of the most sublime chemistry: but these difficulties ought rather to encourage than depress our attempts to arrive at a more intimate knowledge of the powers of nature.

Vegetable bodies.

The organs of vegetables appear to consist chiefly of tubes, adapted to imbibe fluid matter from the earth. This fluid, which is mostly water, rises either by the capillary attraction, by the alternate expansions and contractions which depend on temperature, or by other means; and deposits its impregnations during its transition through the vessels of the plant.

The

The action of the solar light, the agitation produced ^{ORGANIZED} by winds, and the nature of the circumambient air, ^{SUBSTANCES.} are of great importance in these processes. It is ^{Vegetable bodies.} known that vegetables do not thrive in vital air; that they absorb fixed air; and that they emit vital air during the action of light, more especially the strong light of the sun. That they emit plentiful exhalations of various kinds, is obvious from their smell; from the humidity of countries abounding with woods; as well as from the consideration of the short time that would be required to dry the leaves of vegetables, if they did not constantly receive a supply of moisture to recruit what they must lose by constant evaporation. We see therefore that plants are assemblages of vessels, in which water and aerial fluids are received; and by successive mixtures, filtrations, evaporations, or depositions, are either decomposed, or form new compounds. Thus it may arise from the decomposition of water itself, that they emit vital air; while the other principle, or inflammable air, is retained, and enters into the composition of their combustible parts. Or, if the decomposition of water be denied, the vital air may arise from the absorption of fixed air; whose combustible principle (whether it be supposed to be inflammable air, as some philosophers infer; or charcoal, according to others) may be retained, and answer a like purpose; since both these substances are obtained in the inflammation of vegetables.

Animal bodies are of a much more elaborate structure. In these there is a provision for mechanically dividing solid bodies by mastication, which answers

ORGANIZED the same purpose as grinding, pounding, or leviga-
 SUBSTANCES. tion, does in our experiments; namely, that of en-

Animal bodies. larging the quantity of surface to be acted upon by solvents. The process carried on in the stomach appears to be of the same kind as that which we distinguish by the name of digestion; and the bowels, whatever other uses they may serve, evidently form an apparatus for filtering, or conveying off, the fluids; while the more solid parts of the aliments, which are probably of such a nature as not to be rendered fluid but by an alteration which would perhaps destroy the texture of the machine itself, are rejected as useless. When this filtered fluid passes into the circulatory vessels, through which it is driven with considerable velocity by the mechanical action of the heart, it is not only subjected to all those changes which the chemical action of its parts is capable of producing, but is likewise exposed to the air of the atmosphere in the lungs, into which that elastic fluid is repeatedly admitted by the act of respiration. Here it undergoes a change of the same nature as happens to other combustible bodies when they combine with its vital part. This vital part becomes condensed, and combines with some principle emitted from the blood; at the same time that it gives out a large quantity of heat, in consequence of its own capacity for heat being diminished. It has not been ascertained whether the substance which converts the inspired vital air into fixed air (of which a portion is expired from the lungs together with the noxious or phlogificated air) be inflammable air or charcoal; and it has likewise been doubted whether any part of the vital air is absorbed by

by the blood. Later experiments of Dr. Priestley ^{ORGANIZED} shew, however, that this last event does actually take ^{SUBSTANCES.} place*.

It would lead us too far from our purpose, if we were to attempt an explanation of the little we know respecting the manner in which the secretions, or combinations, that produce the various animal and vegetable substances, are effected; or the uses of those substances in the œconomy of plants and animals. Most of them are very different from any of the products of the mineral kingdom. We shall therefore only add, that these organized beings are so contrived, that their existence continues, and all their functions are performed, as long as the vessels are supplied with food, or materials, to occupy the place of such as are carried off by evaporation from the surface, or otherwise; and as long as no great change is made, either by violence or disease, in those vessels, or the fluids they contain. But as soon as the entire process is interrupted in any very considerable degree, the chemical arrangements become altered; the temperature in land animals is changed; the minute vessels are acted upon, and destroyed; life ceases; and the admirable structure, being no longer sufficiently perfect, loses its figure, and returns, by new combinations and decompositions, to the general mass of unorganized matter, with a rapidity which is usually greater, the more elaborate its construction.

Nutrition.

Disease.

Death.

The parts of vegetable or animal substances may be obtained, for chemical examination, either by sim-

* Phil. Transf. lxxx. 106.

**ORGANIZED
SUBSTANCES.**

Various methods of separating the parts of animal or vegetable substances.

ple pressure, which empties the vessels of their contents; by digestion in water, or in other fluids, which dissolve certain parts, and often change their nature; by destructive distillation, in which the application of a strong heat alters the combination of the parts, and causes the new products to pass over into the receiver, in the order of their volatility; by spontaneous decomposition, or fermentation, wherein the component parts take a new arrangement, and form compounds, which did not, for the most part, exist in the organized substance; or, lastly, the judicious chemist will avail himself of all these several methods, singly, or in combination. He will, according to circumstances, separate the parts of an animal or vegetable substance by pressure, assisted by heat; or by digestion, or boiling in various fluids added in the retort which contains the substance under examination. He will attend particularly to the products which pass over, whether they be permanently elastic, or subject to condensation in the temperatures we are able to produce. In some cases, he will suffer the spontaneous decomposition to precede the application of chemical methods; and in others he will attentively mark the changes which the products of his operations undergo in the course of time, whether in closed vessels, or, exposed to the open air. Thus it is that, in surveying the ample field of nature, the philosophical chemist possesses numerous means of making discoveries, if applied with judgment and sagacity; though the progress of discovery, so far from bringing us nearer the end of our pursuit, appears continually to open new scenes; and, by en-

larging our powers of investigation, never fails to point out additional objects of enquiry.

ORGANIZED
SUBSTANCES.

In treating of the products of the vegetable kingdom, we shall attend rather to the processes by which we obtain them, than to any arrangement supposed to exist among their principles. In this way, the order will consist, first of principles not saline, obtained in a degree of heat not exceeding that of boiling water; secondly, saline principles, obtained by pressure, or mere solution in water or ardent spirit; thirdly, saline principles, obtained by strong heat, or by the action of nitrous acid; fourthly, the products of destructive distillation; and, lastly, the products of spontaneous decomposition, or fermentation.

Vegetable products arranged.

CHAP. II.

CONCERNING SUCH PRINCIPLES OF VEGETABLES AS
DO NOT EXHIBIT SALINE PROPERTIES, AND ARE
OBTAINED WITHOUT THE APPLICATION
OF ANY GREATER HEAT THAN THAT
OF BOILING WATER, AND WITHOUT
THE ACTION OF ANY SOLVENT
BUT WATER, OR ARDENT
SPIRIT.

**VEGETABLE
PRINCIPLES.**

Juices and ex-
tracts.

Purification.

Manipulation.

THOSE immediate principles of vegetables, which do not evidently exhibit saline properties, are called juices, when they flow out of incisions made in the living plant, or are obtained by simple pressure; and extracts, when rendered thick by evaporation of part of the water they contain. The juices of plants are purified by suffering their grosser parts to subside, or by filtration. In some cases, the fluid is rendered clearer, by simply heating it in a water-bath, which causes part to take the form of a coagulum.

Dry plants, or woods, or seeds, are either rasped, pounded, or ground, to separate their parts, and may be macerated, boiled, or digested* in water, or spirit of wine; or the insoluble parts may be subjected to pressure, to force out their fluid contents. These fluids may be purified by means similar to those which are applied to the expressed juices of plants.

The

The principles of plants which are not of a saline nature, and are obtained without destroying them by heat, are—1. Gum, or mucilage, which is soluble in water, but not in ardent spirit. 2. Sugar, which is soluble both in water and in ardent spirit. 3. Starch, which, though insoluble in either of these fluids, forms a paste with water, especially if heated. 4. Vegetable gluten, which is neither soluble nor diffusible in water or ardent spirit; has a tenacious consistence when recently prepared; but does not imbibe water after it has once been dried. 5. Fat oils, which are insoluble in water or ardent spirit, and are either fluid, or fusible, without alteration, by a moderate heat. 6. Volatile or essential oils, which are soluble in ardent spirit, but not in water, and rise totally in distillation. 7. Camphor, which differs from essential oils in being more concrete, more volatile, and in being totally soluble, without alteration, in concentrated acids. 8. Resins, which differ from essential oils, in being decomposable by heat; and from camphor, in being changed by acids. 9. The aromatic principle, or vegetable principle of smell. 10. Colouring matters.

VEGETABLE
PRINCIPLES.

Enumeration of
such principles
of vegetables as
are not saline.

The juices or extracts of plants, in general, contain both gum and resin, which may be separated by their respective solvents, water and ardent spirit. These appear to exist together in the plant, forming a compound of a soapy or saponaceous nature.

Juices or ex-
tracts.

Gum is a substance very well known. It is usually transparent, more or less brittle when dry, and gives a thick, viscid, and gluey consistence to water in which it is dissolved. Gum is usually obtained by wounding the

Gum.

VEGETABLE the trunks or branches of trees, such as the plum, the
PRINCIPLES. pear, the cherry tree, &c.; and is distinguished by various denominations, according to the plant from which it is obtained. It is observable that saccharine fruits, when four and unripe, are found to contain gum, and an acid; whence the saccharine matter seems to be formed of these principles. This is rendered much more probable from the consideration that gum and sugar afford nearly the same products by heat, or by distillation with the nitrous acid, as we shall hereafter shew.

Mucilage or
gum.

Sugar.

Manufacture of
sugar.

Sugar may be reckoned among mucilages or gums: it appears to be brought nearer to the saline state. Ardent spirit dissolves it as well as water. The peculiar taste of this substance indicates its presence in a number of fruits and other vegetables; but it is most plentifully obtained from the sugar cane, which is cultivated in warm climates. The juice of the plant is expressed by passing it between two cylinders of iron, placed perpendicularly. This fluid, which is thick and tenacious, is boiled together with lime and alum, and is afterwards suffered to crystallize by standing in a vessel, in the bottom of which are holes imperfectly stopped, in order that the syrup may drain off. The process of refining sugar appears to be capable of considerable improvement. It is not clearly ascertained what effect the lime and alum have upon the process; but it is highly probable that a part of the sugar is burned in the boiling, and converted into an acid, which combines with the lime, and would else impede the crystallization of the sugar. The coarse sugar thus produced, is refined by subsequent solution in water, and boiling with a small proportion of lime, together
 with

with bullock's blood or eggs. These fluids, which are VEGETABLE PRINCIPLES. at first diffused through the liquor, have the property of becoming concrete, as the temperature increases, and rise in the form of skum to the surface of the fluid, carrying with them the impurities, and rendering it more clear and transparent. The filtered liquor is then either poured into moulds, in which, by a confused crystallization, it forms loaf sugar; or else it is exposed in heated rooms, where, by a gradual crystallization, it forms sugar-candy. Manufacture of sugar.

The habitude of sugar with water greatly resembles that of salts; but it has not been ascertained that it contains any salt ready formed, except a small proportion of alkali. It is more inflammable than gums.

Flour, or the pulverized substance of farinaceous seeds, has a strong analogy to the gummy and saccharine mucilages. These seeds, if moistened, and exposed to a moderate or summer temperature, become in a great measure converted into saccharine mucilages, as happens in the process of converting barley into malt. Flour, or the powder of farinaceous seeds. Wheat flour may be taken as an example of the composition of these seeds, before they begin to vegetate afresh. If this be made into a paste, and washed in a large quantity of water, it is separated into three distinct substances; a mucilaginous saccharine matter, which is really dissolved in the liquor, and may be separated from it by evaporation; starch, which is suspended in the fluid, and subsides to the bottom by repose; and gluten, which remains in the hand, and is tenacious, very ductile, somewhat elastic, and of a brown grey colour. The first of these substances does not essentially differ from other saccharine mucilages. Wheat flour washed in water.

VEGETABLE
PRINCIPLES.

Starch.

lages. The second, namely the starch, forms a gluey fluid by boiling in water, though it is scarcely, if at all, acted upon by that fluid, when cold. Its habitudes and products with the fire, or with nitrous acid, are nearly the same as those of gum, and of sugar. It appears to be as much more remote from the saline state than gum, as gum is more remote from that state than sugar.

Vegetable glu-
ten.

The vegetable gluten, though it existed before the washing in the pulverulent form, and has acquired its tenacity and adhesive qualities from the water it imbibed, is nevertheless totally insoluble in that fluid. It has scarcely any taste. When dry it is semi-transparent, and resembles glue in its colour and appearance. If it be drawn out thin, when first obtained, it may be dried by exposure to the air; but, if it be exposed to warmth and moisture while wet, it putrefies like an animal substance. The dried gluten, applied to the flame of a candle, crackles, swells, and burns, exactly like a feather or piece of horn. It affords the same products by destructive distillation as animal matters do; is not soluble in ardent spirit, oils, or ether; and is acted upon by acids and alkalis, when heated.

Fat oils.

Fat oils are obtained by pressure from the emulsive seeds or kernels of vegetables: they are generally fluid in the temperature of the atmosphere, but some of them have a considerable degree of firmness or solidity. They have a very smooth feel; are mostly without smell or taste; require a degree of heat much superior to that of boiling water, to cause them to rise in ebullition; and cannot be set on fire, unless heated to this degree.

degree. The use of the wick of a lamp consists in bringing small portions of oil to its extremity, by the capillary attraction, where they become successively volatilized and inflamed. Oils are remarkably less sonorous than water, when poured out. Fat oils, not being at all dissipated by the heat of the atmosphere, make a permanent greasy spot when they fall on porous substances.

VEGETABLE
PRINCIPLES.

Fat oils :

These oils are decomposed by distillation, and afford a small quantity of water loaded with a peculiar acid, a light oil, a dense oil, inflammable air, and fixed air. The residue consists of a small quantity of charcoal.

—decomposed
by distillation :

Fat oils, by exposure to the air, become rancid ; and exhibit a disengaged acid, which may be washed off by water. When they are exposed to the air in a thin coat upon the surface of water, they become more consistent, like wax, by absorbing the vital part of the atmosphere ; the aerated or dephlogisticated marine acid produces this change more speedily. Agitation in water separates a mucilage from them. They combine with magnesia, and with lime, which convert them into saponaceous compounds. With the pure alkalis they form common soap. They do not unite with the volatile alkali but by long trituration.

—habitudes
with air, water,
and various
substances.

The mineral acids unite with fat oils, and form compounds, or imperfect soaps. Fuming nitrous acid causes them to take fire, as has already been observed. Sulphur is soluble in fat oils, by a digesting heat ; and is gradually deposited in part from them, in a crystalline form, by cooling.

These sulphureous compounds are called balsams of sulphur.

Bitumens

VEGETABLE PRINCIPLES. Bitumens and amber are soluble in fat oils, and form varnishes.

Volatile or essential oils : Volatile or essential oils have usually a strong aromatic smell, are sufficiently volatile to rise with the

heat of boiling water, and are in general soluble in spirit of wine. They exist in almost all fragrant vegetables; and in the various plants they are found either in the wood, the root, the bark, the leaves, the flowers, the fruits, &c. They differ very much in the degree of fluidity they possess at a common temperature, and their colours are various. They are obtained either by expression, as from the peel of oranges and lemons, or by distillation with water.

—obtained by pressure or by distillation :

Some essential oils, such as those of cinnamon, saffra, and other foreign plants, sink to the bottom of the water with which they come over; others float at the top. It is easy to distinguish the adulteration of volatile oils, either by pouring ardent spirit upon them, which will not dissolve the fat oil they may be contaminated with; or if they be dropped on paper, and held to the fire, in this case they leave a greasy spot behind. If oil of turpentine be fraudulently added to them, its smell betrays its presence when treated in this manner.

—are inflammable.

Volatile oils are very inflammable. By exposure to air, they become thick in process of time, and assume the character of resins.

Combinations.

They unite with difficulty to lime and alkalis. The vitriolic acid converts them into bitumens; but, if diluted, it renders them saponaceous, as does likewise the muriatic acid. Nitrous acid inflames them.

They unite very readily with sulphur, and form balsams.

fams. Mucilages and sugar render them soluble or VEGETABLE PRINCIPLES.
diffusible in water.

Camphor is a peculiar vegetable substance, which Camphor.
resembles volatile oil, and is in fact deposited from
some of the volatile oils by long standing. It has
been obtained in small quantities by distillation with
water from thyme, rosemary, sage, and other fragrant
plants. The camphor of commerce is obtained from a
species of laurel, which grows in China and the Indian
islands, by distillation of the wood and other parts of
the tree with water. The camphor rises by the heat,
and is afterwards purified by a repetition of the pro-
cess, with the addition of about one-twelfth of its
weight of lime.

This substance is much more volatile than essential Characters of
camphor :
oils. It cannot be preserved without loss, but in closed
vessels, and even in these it sublimes by the heat of
summer. Water does not dissolve it; but it is plenti-
fully soluble in spirit of wine, in ether, and in concen-
trated acids; from all which it is separated, without
alteration, by the addition of water. Fixed and vola-
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and deposit crystals in the form of a beautiful vege-
tation by cooling.

A peculiar acid is formed by distillation of the ni—its acid.
trous acid from this substance.

Resins are dried juices of plants, which are of the Resins, how
obtained.
nature of essential oil. They usually flow from wounds
made in the trunks of trees for that purpose. Fragrant
resins have been distinguished by the name of balsams.
Almost all the concrete juices, distinguished by the
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Ff

dissolves

VEGETABLE
PRINCIPLES.

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diffusible in water.

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This substance is much more volatile than essential oils. It cannot be preserved without loss, but in closed vessels, and even in these it sublimes by the heat of summer. Water does not dissolve it; but it is plentifully soluble in spirit of wine, in ether, and in concentrated acids; from all which it is separated, without alteration, by the addition of water. Fixed and volatile oils dissolve camphor, with the assistance of heat, and deposit crystals in the form of a beautiful vegetation by cooling.

A peculiar acid is formed by distillation of the nitrous acid from this substance. —its acid.

Resins are dried juices of plants, which are of the nature of essential oil. They usually flow from wounds made in the trunks of trees for that purpose. Fragrant resins have been distinguished by the name of balsams. Almost all the concrete juices, distinguished by the name of resins, are soluble in ardent spirit. Water

F f

dissolves

VEGETABLE
PRINCIPLES.

dissolves none of them. They are inflammable, and burn with much smoke. In closed vessels they do not rise wholly by heat, like essential oils, but are decomposed.

Resinous sub-
stances.

A very considerable number of resinous substances are known and used in the arts. Common resin of the pine, the resin of the fir, pitch, tar, and turpentine, are among those which are soluble in spirit of wine, and are of the nature of essential oils. Copal, and the elastic substance called caoutchouc, which is the inspissated juice of a tree from Africa, are usually reckoned among resins; though neither spirit of wine nor water dissolves them. They are soluble however in oils, by the assistance of heat, and seem to be of the nature of fat oils. The juices called gum resins are variously soluble in the different menstrua, according to the nature and abundance of their component parts.

Principle of
smell in vege-
tables.

The principle of smell in plants appears to be of an exceedingly subtle nature. It seems in general to reside in the essential oil, and composes an extremely small part of the weight of vegetables, as may be inferred from the loss of fragrance sustained by essential oils, with little or no loss of their weight. This however does not necessarily suppose that the whole principle of smell has flown off; because it may with equal probability be supposed to have entered into combination with some of the other principles of the substance which afforded it. Distillation with spirit of wine is used to extract the fragrant principle from plants. A considerable proportion of this matter may be obtained by distillation with water, in which it comes over

probably

probably diffused with a small proportion of essential VEGETABLE
PRINCIPLES.
oil. It has been supposed to consist of an elastic fluid }
of a peculiar nature.

The knowledge of the colouring matters of vegetables is of great importance to society, as the art of dyeing depends on the application of these substances. Much however remains to be ascertained concerning them. If the doctrine of Newton were incontrovertibly established, that the colours of bodies depend solely upon the magnitude of the integrant particles of bodies, we might assert, without hesitation, that all the principles of bodies might be applied in theory to the production of any assignable colour; and we might thence infer, that the colour of plants is not produced by the diffusion of coloured particles of any particular kind, but by the configuration of the parts taken in general. But we are not sufficiently advanced in any part of the knowledge of nature, to reason with safety, without constant recurrence to the test of experiment. In this way we find that the chemical solvents, in many instances, deprive plants of their colour, at the same time that they themselves acquire it; doubtless by solution of the colouring matter, which they again deposit upon bodies prepared for that purpose. Water dissolves the colouring matter of various substances, such as logwood, madder, &c. The stuffs to be dyed require, in many cases, the previous soaking in a solution of alum, vegetable alkali, or other salts, to prevent their giving the colour out again to water. Other colouring principles are soluble in oils, such as alkanet; and many which are not soluble in water, are

-are taken up
by chemical
solvents.

F f 2

taken

VEGETABLE taken up that fluid, by the intervention of an alkali.

PRINCIPLES. The art of dyeing, or of fixing colouring matter upon

Art of dyeing. various stuffs, appears to depend upon the chemical affinities of the colouring matters either with the stuffs themselves, or the matters in which they are previously infused. The condition required in a good dye appears to be, that the colouring matter shall be precipitated on the stuff, and form a compound not soluble in the liquids to which the stuff will probably be exposed. Thus, for example, printed or dyed linens or cottons ought to resist the action of soap and alkalis; and woollens ought more particularly to withstand the action of acids, such as lemons, vinegar, &c. which may accidentally fall on them.

Lakes.

Certain colours, called lakes, are prepared by dissolving the vegetable colouring matters, and precipitating them by the addition of some other substance. Thus, for example, if madder be boiled in water together with an alkali, and alum be then added, the earth of the alum will be precipitated together with the colouring matter, with which it will form an insoluble pigment.

C H A P. III.

CONCERNING THE SALINE PRINCIPLES OF PLANTS
OBTAINED BY PRESSURE, OR BY THE APPLI-
CATION OF WATER OR ARDENT SPIRIT;
PARTICULARLY THE ACIDS OF LEMONS,
OF APPLES, OF NUT-GALLS, AND
OF BENZOIN.

THE saline principles of plants are either such as VEGETABLE
are found in the mineral kingdom; namely, SALTS.
vitriolated tartar, Glauber's salt, nitre, common salt, Mineral salts
and the fixed alkalis; or they are such as are pe- found in vege-
culiar to this kingdom. The mineral salts are sup- tables.
posed to have entered into the vessels of the plants
which afford them, and to have remained there un-
altered. The salts peculiar to vegetables are, for the Peculiar salts
most part, of an acid nature. They consist of the enumerated.
acids of lemons and of apples, which are obtained in
an impure state by pressure; the acid of nut-galls,
and the acid of benzoin; the salts of tartar and of
sorrel, which contain a portion of alkali; and such
acids as are formed by distilling the nitrous acid from
vegetable substances, which are those of sugar, cam-
phor, cork, &c. Destructive distillation likewise de-
velops or forms peculiar acids. Those obtained from
tartar, from mucilage or sugar, and from wood, have
only been examined.

VEGETABLE
ACIDS.

Various methods of preserving lemon-juice:

—by oil:

—by evaporation:

—by freezing.

The juice of lemons, or limes, has all the characters of an acid of considerable strength. On account of the mucilaginous matter with which it is mixed in its first state, it is very soon altered by spontaneous decomposition. Various methods have been contrived to prevent this effect from taking place, in order that this wholesome and agreeable acid might be preserved for use in long voyages, or other domestic occasions. The juice may be kept in bottles under a thin stratum of oil, which indeed prevents, or greatly retards, its total decomposition; though the original fresh taste soon gives place to one which is much less grateful. In the East Indies it is evaporated to the consistence of a thick extract. If this operation be carefully performed by a very gentle heat, it is found to be very effectual. When the juice is thus heated, the mucilage thickens, and separates in the form of flocks; part of which subsides, and part rises to the surface: these must be taken out. The vapours which arise are not acid. If the evaporation be not carried so far as to deprive the liquid of its fluidity, it may be long preserved in well-closed bottles; in which, after some weeks standing, a farther portion of mucilage is separated, without any perceptible change in the acid.

Of all the methods of preserving lemon juice, that of concentrating it by frost appears to be the best; though, in the warmer climates, it cannot conveniently be practised. Lemon juice, exposed to the air in a temperature of between 50° and 60°, deposits in a few hours a white semi-transparent mucilaginous matter, which leaves the fluid, after decantation and filtration, much

much less alterable than before. This mucilage is VEGETABLE ACIDS. not of a gummy nature, but resembles the gluten of wheat in its properties: it is not soluble in water, when dried. More mucilage is separated from lemon juice by standing in closed vessels. If this depurated lemon juice be exposed to a degree of cold of about seven or eight degrees below the freezing point, the aqueous part will freeze, and the ice may be taken away as it forms; and if the process be continued until the ice begins to exhibit signs of acidity, the remaining acid will be found to be reduced to about one-eighth of its original quantity, at the same time that its acidity will be eight times as intense; as is proved by its requiring eight times the quantity of alkali to saturate an equal portion of it. This concentrated acid may be kept for use; or, if preferred, it may be made into a dry lemonade, by adding six times its weight of fine loaf sugar in powder*.

The above processes may be used when the acid of lemons is wanted for domestic purposes; because they leave it in possession of the oils, or other principles, on which its flavour peculiarly depends. But in chemical researches, where the acid itself is required to be had in the utmost purity, a more elaborate process must be used. Boiling lemon juice is to be saturated with powdered chalk, whose weight is to be noted. The neutral saline compound is scarcely more soluble in water than selenite: it therefore falls to the bottom; while the mucilage remains suspended in

* Georgius, quoted by Fourcroy, iv. 33.

VEGETABLE ACIDS. the watery fluid, which must be decanted off. The remaining precipitate must then be washed with warm water until it comes off clear. To the powder, thus depurated of acid of lemons, edulcorated, a quantity of vitriolic acid, sufficient to saturate the chalk, and diluted with ten parts of water, must be added, and the mixture boiled a few minutes. The vitriolic acid combines with the lime, and forms selenite, which remains behind when the cold liquor is filtered; while the disengaged acid of lemons remains dissolved in the fluid. This last must be evaporated to the consistence of a thin syrup; and vitriolic acid must be then added in small portions, to precipitate the lime, if any should still remain in combination with acid of lemons. When no more precipitate is afforded by the addition of vitriolic acid, a farther evaporation separates the pure acid of lemons in crystals. It is necessary that the vitriolic acid last added should be rather in excess; because the presence of a small quantity of lime will prevent the crystallization. This excess will be found in the mother water*.

Characters.

The concrete acid of lemons remains consistent in the air, is very soluble in water, and exhibits strong acid properties. Its watery solution is decomposed by a slow putrefaction. It unites with the alkalis and earths, silex excepted; and forms peculiar neutral salts, which have not yet been much examined. Several of the metallic substances are likewise acted upon by it; and it would probably dissolve all their calces.

* Scheele's Essays, Eng. Translation, p. 361; or Crell's Journal for 1784.

The acid which abounds in four or unripe fruits exhibits distinct properties. As it is plentifully obtained from apples, the first examiner, Scheele, has denominated it the acid of apples. In order to obtain it, the juice of four apples is expressed from the fruit, and saturated with vegetable alkali. To this liquor a solution of the vitriolic salt of lead must be very gradually added. A double decomposition takes place. The vitriolic acid combines with the alkali, and forms vitriolated tartar; at the same time that the acid of apples, uniting with the lead, forms an insoluble precipitate. When the precipitate nearly ceases to fall down, the solution of sugar of lead must be added cautiously, by a drop at a time, until no more precipitate is afforded. The vitriolated tartar may be washed off from the precipitate; and diluted vitriolic acid being then poured on the precipitate, sugar of lead is again formed, and the acid of apples is set at liberty.

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ACIDS.

Method of purifying the acid of apples.

In such fruits as contain the acid of lemons as well as that of apples, the separation of one from the other is accomplished by the following process. The juice of gooseberries, for example, is evaporated to the consistence of syrup: pure ardent spirit being poured upon this, dissolves the acids, and leaves the mucilage, which may be separated by filtration. The ardent spirit being then evaporated, and water added, the acids must be saturated with chalk. The solution being boiled for a few minutes, the calcareous salt of lemons falls to the bottom, on account of its difficult solubility; while the other salt, consisting of the acid of apples, united to lime, remains suspended, and may

confe-

Separation of the acids of lemons and of apples.

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ACIDS.

consequently be decanted off. This neutral salt not being soluble in spirit of wine, may be precipitated by the addition of a proper quantity of that fluid; which, at the same time, deprives it of a portion of saponaceous and saccharine matter. The coagulum, or precipitate, which consists for the most part of the acid of apples, perfectly neutralized by lime, may be dissolved in boiling water. An addition of sugar of lead forms a precipitate by double affinity, as in the first case, consisting of the acid of apples united to lead; and this washed precipitate may be decomposed by the addition of diluted vitriolic acid, which combines with the lead, and sets the acid of apples at liberty.

Characters.

This acid exhibits peculiar properties. It cannot be obtained in crystals; and forms deliquescent salts with the three alkalis, and also with magnesia. Its saline combination with lime is crystallizable; and with clay it forms a salt of very sparing solubility. It dissolves iron, with which it forms a salt that does not crystallize. With zinc it forms a salt which affords beautiful crystals. It precipitates the nitrous solutions of mercury, lead, silver, and gold, in the metallic state: when nitrous acid is distilled from it, it is converted into acid of sugar.

The astringent
principle.

Many vegetable substances, such as the husks of nuts, the bark of the oak, the nut-gall, and other vegetable matters, abound with a substance which has been distinguished by the name of the astringent principle. Its distinguishing character is that of precipitating iron from its solutions in acids, of a black colour. The nut-gall is chiefly used for this, and other purposes

purposes wherein the application of this property is required; and, as it resembles acids in its properties, the principle has been called the acid of galls.

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ACIDS.

The acid of galls is obtained by macerating the nut-gall in water. This infusion reddens turnsole and blue paper. The acid is soluble in oils, ardent spirit, and ether. Acids dissolve it, without impairing its property of forming a black precipitate with the solutions of iron: the distilled products of nut-galls likewise possess the same property. It decomposes metallic solutions, and combines with their calces: gold and silver are precipitated by it in the metallic state. It acts upon and dissolves iron directly.

Acid of galls
obtained in solution:

To obtain the acid of nut-galls in a crystallized form, one pound of the powder of galls must be added to six pounds of distilled water, and left to digest for a fortnight, at the temperature of between 70 and 80 degrees; after which, the fluid must be filtered, and left to evaporate spontaneously in the open air, in a stone-ware or glass vessel. The fluid becomes mouldy, and covered with a thick glutinous pellicle; abundance of glutinous flocks fall down; and in the course of two or three months the sides of the vessel appear covered with small yellowish crystals, which are likewise very abundant at the under surface of the pellicle which covers the liquor. The fluid must then be decanted; and ardent spirit, being poured upon the mucilaginous deposition, the crystals and the pellicle, dissolves the salt by the assistance of heat, without touching the mucilage; and, by evaporation of this spirituous solution, the pure gallic acid is obtained in small brilliant crystals, of a grey colour inclining to yellow.

—in the crystallized form.

This

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ACIDS.

Page 310.
General characters and habits of the acid of galls.

This acid, on account of its long exposure to the air, may consist either of a principle existing in the galls, or of that principle converted into an acid. It has the following properties: It precipitates martial vitriol, and other salts of iron, of a beautiful black colour, and strongly reddens the tincture of turnsole: when heated, with contact of air, it swells up, and burns, leaving a coal behind of difficult incineration: by distillation, with a gentle heat, part of the acid comes over dissolved in the water of crystallization: another portion sublimes undecomposed in the form of silky crystals; and a strong heat separates a few drops of oil, with fixed and inflammable air.

The acid of galls is soluble in twenty-four parts of cold water, or three of boiling water. It is much more soluble in spirit of wine; four parts of this being sufficient at the common temperature, or one when boiling hot. With lime, magnesia, or ponderous earth, it forms salts which are soluble in water: it unites readily with the alkalis, and forms compounds, which have not been much attended to. The action of the nitrous acid converts it into the acid of sugar. This acid precipitates gold, silver, mercury, copper, iron, and bismuth, from their solutions; but it does not affect those of platina, zinc, tin, cobalt, and manganese.

Benzoin.

The fragrant resin called benzoin affords a peculiar concrete acid by sublimation, which is about one tenth of the weight of the resin itself, but varies in different specimens. This acid exists ready formed in the benzoin; but cannot easily be washed out by water,

water, on account of the resin which defends it. The best method of obtaining it in the humid way is the following: Lime-water is made by slaking four ounces of quick-lime with twelve ounces of water; and, as soon as the ebullition is over, eight pounds more of water are to be added. Six ounces of this lime-water are to be mixed by agitation with one pound of benzoïn in powder, and the whole of the lime-water is then to be added; the mixture being exposed to heat over a gentle fire for half an hour (during which time it must be continually agitated, to prevent the powder from coagulating), is afterwards suffered to cool, and settle for several hours. The clear liquor must then be decanted, and the residue boiled for half an hour, with eight pounds of water; which, after subsidence and decantation, must be added to the clear fluid of the first boiling. The ebullition of the residue of the matter must be again twice repeated, and the decanted lixiviũs added to the foregoing. All these waters are then to be evaporated to two pounds; during which operation a small quantity of resin falls down. When the evaporated liquor is cool, a quantity of marine acid must be added drop by drop, with constant stirring, till there be no more precipitation, or till the mass has a fourish taste. The precipitate is the acid of benzoïn.

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ACIDS.

Method of obtaining the acid of benzoïn in the humid way.

The rationale of the above process is this: The lime unites with the acid of benzoïn during the ebullition: the evaporation separates a small quantity of resin; and diminishes the aqueous fluid so much, that in the subsequent part of the operation the acid of benzoïn may fall down, and be separated for want of a suffi-

Rationale.

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Method of ob-
taining the acid
of benzoïn.

a sufficient quantity of water to dissolve it. The marine acid, which is added last of all, seizes the lime by its stronger affinity, and forms a soluble salt; while the acid of benzoïn, which is disengaged, falls down, on account of its sparing solubility. The acid thus obtained has the form of a very fine powder. If it be required in the form of silky threads, it may be dissolved in boiling water, and strained through a cloth. As cold water dissolves little more than one five hundredth part of its weight, though boiling water dissolves about one twentieth of this acid, the greatest part of the acid separates by cooling.

Its characters.

The acid of benzoïn combines with the soluble earths and alkalis, and forms compounds, which have been little attended to. It is soluble in the vitriolic and nitrous acids; and may be again separated, without alteration, by the addition of water. Its habitudes with these acids, particularly the latter, when heated, have not been satisfactorily ascertained. If its nature be changed by distillation with nitrous acid, it seems probable that it is effected with much more difficulty than is experienced with other vegetable acids.

CHAP. IV.

CONCERNING THE ACIDS OF TARTAR AND OF
SORREL.

THE two acids which are usually found in combination with a portion of the vegetable alkali, are the acid of tartar and of wood sorrel. Tartar has for a long time been considered as one of the products of the vinous fermentation; but it exists ready formed in must, in verjuice, and is likewise obtained in other chemical processes with vegetables. However, it is obtained, for all the purposes of commerce, from wine; during the insensible fermentation of which liquid, it is gradually deposited on the sides of the casks.

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Tartar.

Crude tartar is seldom used in medicine or philosophical chemistry; the refined tartar is known by the name of cream, or crystals, of tartar. The purification of this salt is effected by dissolving it in boiling water, filtering, and suffering it to crystallize by cooling; the crystals are again boiled, together with an argillaceous earth, to deprive them of their impurities, which are carefully scummed off; or else with whites of eggs, which answer the same purpose. When no more scum arises, a saline pellicle is formed at the top of the liquor, at the same time that the crystallization goes forward at the bottom. This salt, after the earth is washed off with cold water, is sold under the name of

Cream and
crystals of tar-
tar.

VEGETABLE ACIDS. of cream, and crystals of tartar. The cream of tartar consists of the minute crystals which are formed at the top of the liquor, and the crystals of tartar are formed at the bottom.

Characters of purified tartar.

The taste of this purified salt is less vinous than that of the crude tartar. When exposed to heat, it boils up, emits an epyreumatic smell, and becomes black and coaly; a stronger heat in an open fire entirely dissipates its acid part, and leaves the vegetable alkali in a mild state, or combined with fixed air. Its volatile products, by a gradual fire, are water, an acid, and an empyreumatic oil, which is followed by some volatile alkali, and a large quantity of fixed air. Crystals of tartar are soluble in twenty-eight parts of boiling water; three-fourths of the salt are deposited in cooling. If the solution of this salt be left exposed to the air, it is very slowly decomposed; mucilage is deposited, the acid disappears, and after eighteen months the liquid is found to contain the vegetable alkali, amounting to nearly one-fourth of the weight of the tartar. This quantity of alkali being nearly the same as is afforded by the incineration of tartar, is a proof that the vegetable alkali is not a product of fire, as was formerly supposed.

Habitudes.

The habitudes of tartar with clay and ponderous earth have not been ascertained. Magnesia forms with it a soluble salt. Chalk unites with the excess of acid in the tartar, and separates the neutral salt; consisting of the vegetable alkali, saturated with the tartareous

Soluble tartar.

acid, which is known by the name of soluble tartar. If the vegetable alkali be added to a solution of cream of tartar, in such a quantity as to saturate it, the same neutral

neutral salt, or soluble tartar, will be formed. This ^{VEGETABLE} has a bitter taste, and is decomposed by heat, affording ^{ACIDS.} the same volatile products as cream of tartar. It is Soluble tartar. soluble in four parts of water heated to 110°, and affords crystals which are slightly deliquescent.

It is a curious fact, though by no means singular in ^{Curious fact.} the history of neutral salts, that two very soluble substances, such as the vegetable alkali, and the acid of tartar, should compose a salt of so little solubility as the crystals of tartar; more especially, as the point of the greatest difficulty of solution is not that at which they are saturated, but that in which the acid so considerably abounds.

If to twenty ounces of purified tartar, dissolved in ^{Manufacture of} four pounds of boiling water, the pure crystallized ^{Rochelle salt.} mineral alkali be added, until the saturation be complete, as may be judged by any additional quantity producing no effervescence; the alkali last added will combine with the superfluous acid of the tartar, and form the neutral combination called the salt of Seignette, or Rochelle salt; at the same time that the residue of the tartar will become converted into soluble tartar. By evaporating the liquor nearly to the consistence of syrup, the Rochelle salt is obtained in beautiful regular prisms, of six or eight sides, which effloresce in the air, and are decomposed by heat in the same manner as soluble tartar.

By the same treatment with volatile alkali, an ammoniacal tartareous salt is formed, which affords crystals that effloresce in the air.

If the mineral acids be added to tartar, they com- ^{Ammoniacal} bine with its alkali, and form the same salts as they ^{salt of tartar.}

G g

would

VEGETABLE ACIDS. would have produced by direct union with the vegetable alkali.

Tartar.

Tartar has long been an object of attention with chemists, and it is used as an acid in many of the arts. This salt appears to be capable of uniting without decomposition, and forming triple salts with most of the metals.

Method of obtaining the acid of tartar :

The pure acid of tartar may be obtained by saturating three parts of cream of tartar with chalk or lime ; the former of which combines with the superfluous acid, and the latter seizes the whole. The calcareous tartar, which, on account of its insolubility, remains at the bottom, is then to be well washed, and digested with about one part of vitriolic acid, together with a sufficient quantity of water. In this manner the acid of tartar is disengaged. The selenite formed by the combination of the vitriolic acid and the lime, will be separated, and fall down, by evaporating the water ; and the acid which remains may be crystallized by further evaporation and cooling.

—or otherwise. Or, more simply, one pound of cream of tartar may be boiled in five or six pounds of water, and a quarter of a pound of clear and colourless dense vitriolic acid may be added by little and little. When a complete solution is obtained, the fluid will then contain disengaged acid of tartar, together with vitriolated tartar, or the neutral salt formed by the union of the vitriolic acid with the vegetable alkali. The vitriolated tartar, being a salt of sparing solubility, will be precipitated by continuing the boiling. When the liquor is evaporated to one half, it is to be filtered ; and if, upon further evaporation, any thing more is precipitated,

pitated, it must be filtered again. The clear liquor ^{VEGETABLE} being then reduced to the consistence of a syrup, and ^{ACIDS.} set by in a temperate or rather warm place, will afford fine crystals of tartareous acid, equal in weight to Acid of tartar : half the cream of tartar employed. If too small a quantity of vitriolic acid has been used, part of the cream of tartar will not be decomposed, but will separate from the liquor along with the vitriolated tartar. It is better therefore to use too little rather than too much.

The crystallized tartareous acid melts, fumes, becomes black, and burns, by the contact of ignited bodies. By distillation it affords an acid phlegm, a small quantity of oil, and much fixed air, together with inflammable air ; leaving behind a coaly residue, which contains neither acid nor alkali. ^{—its characters,}

The crystals of tartareous acid do not change by exposure to air ; they are much more soluble in water than cream of tartar itself. This acid dissolves clay, and forms a salt which, by evaporation, assumes a clear gummy consistence, and does not deliquesce in the air. The same appearance is exhibited with magnesia : with lime, it forms a salt which is scarcely at all soluble ; a due proportion of vegetable alkali converts it into cream of tartar, which falls down if the water of solution be not sufficiently abundant, but is dissolved again if more alkali be added, so as to convert it into soluble tartar. These synthetical operations shew that the tartareous acid is not altered by the process of extracting it from cream of tartar.

With the mineral alkali it forms the Rochelle salt, and with volatile alkali it forms a crystallizable salt.

VEGETABLE
ACIDS.

In this last combination there is a term at which crystals of sparing solubility, like those of cream of tartar, are formed; and in this case likewise the acid of tartar is far from being saturated with the alkali.

This acid is convertible into the saccharine acid by distillation with strong acid of nitre: and it is converted into acetous acid by digestion with water and ardent spirits.

Salt of sorrel: Salt of sorrel is a crystallized salt; so denominated because it is obtained from the wood sorrel, or oxalis acetosella of Linnæus, for the purposes of commerce; though it may be obtained from some other plants. It is in white crystals, whose figure has not been well determined, on account of their minuteness. When it is exposed to distillation in a retort, the acid is partly decomposed; a considerable quantity of acid phlegm comes over, which is without smell or colour, and consists of the acid itself, scarcely altered; and the residue affords vegetable alkali, amounting to somewhat more than one third of the weight of the salt. Exposure to air does not alter the salt of sorrel. It is very sparingly soluble in cold water: but boiling water may take up one sixth part, or more, of its weight; the quantity varying according to the state and purity of the salt, which seems to vary in different specimens.

—action upon
various sub-
stances.

Salt of sorrel acts upon various substances without decomposition. With ponderous earth, magnesia, vegetable alkali, and volatile alkali, it forms triple salts. Lime decomposes it by seizing the whole of the acid, and disengaging the alkali. The attraction of this acid for lime is so strong, that it cannot be disengaged from

from it by any other acid: another process is therefore necessary to be used for obtaining it. With this intention, the superabundant acid is to be saturated with volatile alkali; and into this solution must be poured a solution of ponderous earth in the nitrous acid. The last-mentioned acid combines with the alkalis, forming nitrous ammoniac, and common nitre, both which remain in solution; while the ponderous earth, combining with the acid of sorrel, forms an insoluble compound, which falls to the bottom. This precipitate, after being well washed, may be decomposed by the addition of vitriolic acid, which seizes the earth, and likewise forms an insoluble combination, while the acid is set at liberty. After decantation of the clear liquid, it must be assayed by pouring into it a little at a time of the boiling hot solution of ponderous earth in the acid of sorrel. If there be any excess of vitriolic acid, a precipitate will be formed by its union with the ponderous earth. A due evaporation and cooling of this liquor afford the acid of sorrel, in prismatic four-sided crystals or square plates.

VEGETABLE
ACIDS.

Method of
purifying the
acid of sorrel.

This acid has a considerable degree of strength. Characters. Exposed to heat in a retort, it falls into powder, with the loss of three-tenths of its weight, after which it melts, boils up, at the same time that its colour changes to a brown. An acid phlegm comes over, and part of the acid sublimes without alteration. Fixed air and inflammable air are disengaged during this decomposition of the acid; and their quantity is greater, the more violent the heat.

Boiling water dissolves its own weight of this concrete acid salt, half of which is separated in crystals

Combinations.

G g 3

by

VEGETABLE ACIDS. by cooling. It dissolves clay, and affords a deliquescent mass by evaporation. With ponderous earth it forms a salt scarcely soluble, except there be an excess of acid; in which case it affords transparent crystals, which become opaque, powdery, and insoluble, when the excess of acid is taken up by boiling water. With magnesia, it forms a white powdery salt; and with lime it forms an insoluble compound, which cannot be decomposed in the moist way, because the affinities of these two substances are stronger than any which exist between either of them and other known bodies. From this property, the acid of sorrel is used as the test of the presence of lime, which it precipitates from all its combinations.

Combinations
of the acid of
sorrel.

Synthesis.

If vegetable alkali be gradually added to a solution of this acid in water, a precipitate falls down, which is the salt of sorrel, and contains the acid in excess. A farther addition of alkali saturates the acid, and forms a very soluble salt, which is capable of crystallizing, if the alkali be in excess. With an excess of the mineral alkali it forms a salt of sparing solubility. With volatile alkali it affords a crystallizable salt; and with both these alkalis, if the acid be in excess, it forms a less soluble salt, similar to what happens with the vegetable alkali.

It acts on several of the metals directly, but in general combines more readily with their calces.

This acid does not differ from the acid of sugar. Treatment with nitrous acid converts it into acetous acid and fixed air; or totally into the latter, if the action be rapid.

C H A P. V.

CONCERNING THE VEGETABLE ACIDS PRODUCED OR
DEVELOPED BY DESTRUCTIVE DISTILLATION,
OR BY THE ACTION OF NITROUS ACID.

IN the course of the preceding accounts of the vegetable acids, it may be observed, that they are all subject to great alterations by the action of chemical agents; and they are all subject to spontaneous decomposition. They seem to obtain their acid properties by the combination of a base with the vital part of the air, in the same manner as has been more fully shewn with regard to the mineral acids; but they appear to be of too compounded a nature to retain the order or arrangement of their component parts through those great varieties of temperature to which in general the mineral acids may be subjected. Heat alters the arrangement of their component parts, and separates them from each other in a new form. The products of all vegetable substances, including these acids, are found, when urged by fire, to be water, fixed air, inflammable air, oil, coal, and alkali. If we consider water as decomposable, and consisting of vital and inflammable air; if we consider oil as composed of fixed air and inflammable air; and again, whether we admit charcoal to consist chiefly of inflammable air, according to the opinion of some chemists, or of

VEGETABLE
ACIDS:
ARTIFICIAL.

Considerations
on the compo-
sition and de-
composition of
vegetable bo-
dies..

VEGETABLE ACIDS: the peculiar basis of fixed air, according to others;
ARTIFICIAL. and, lastly, if fixed air be allowed to consist of charcoal united to vital air, whether the charcoal be conceived as a peculiar substance, or as inflammable air in a state of condensation; we shall at length find that the component parts of vegetables are very few; infomuch that, if the foregoing positions were clearly established, they would consist either of charcoal, vital air, and inflammable air, or else of vital air and inflammable air only. From the various proportions of these, in different states of condensation, it would follow, that water, fixed air, oils, mucilages, and acids, are produced; and that the beautiful variety of nature arises from this arrangement and combination.

Simplicity and small number of vegetable principles.

Empyreumatic acids. The first action of fire upon the vegetable acids does not in general alter their combinations so much, but that some other acid comes over together with the elastic products. These acids, which on account of the peculiar smell which they obtain from the fire are called empyreumatic, would probably, on examination, be found to be of various kinds. Those which have hitherto engaged the attention of chemists, are the empyreumatic acid of tartar; the empyreumatic acid of sugar or mucilage, formerly called spirit of honey; and the empyreumatic acid of wood, which is supposed to be the same in all woods, and has been distinguished by the name of spirit of box.

Empyreumatic acid of tartar. The empyreumatic acid of tartar is the acid phlegm which comes over when cream of tartar is exposed to distillation. This acid is impure, on account of some oil which comes over with it, and from which it can only

only be separated by the funnel; because it dilates so suddenly, when an attempt is made to rectify it by a second distillation, that it bursts the vessels. The acid properties of this fluid are sufficiently apparent, though it does not redden the tincture of violets, as it does turnsole and blue paper. It forms peculiar compounds with the earths and alkalis, which have not been much examined, but are very different from those afforded by the acid of tartar.

VEGETABLE
ACIDS:
ARTIFICIAL.
Empyreumatic
acid of tartar;

When insipid gummy saccharine or farinaceous mucilages are exposed to distillation, an empyreumatic acid comes over, of a reddish yellow colour, and a bitter, acrid, and sour taste. By rectification with the addition of clay, the acid comes over clear, and less empyreumatic. It does not afford crystals, but may be concentrated by freezing, which converts its aqueous part into ice. In this state it strongly reddens blue vegetable colours, and forms a red spot where it falls on the skin. By distillation, cautiously managed in close vessels, it may be converted for the most part into fixed and inflammable air.

—of sugar of
mucilage:

The empyreumatic acid of sugar attacks and dissolves the soluble earths and alkalis. It corrodes lead, copper, tin, and iron: but the compounds it forms with these bodies have been little attended to.

Box, birch, and other woods, when exposed to distillation, afford that peculiar acid which is so offensive to the eyes when the smoke of a smothering wood fire forces itself into an apartment. This acid has considerable strength. The oil which comes over with

—of wood.

VEGETABLE with it, may be separated, either by standing for some
ACIDS : months, or by rectification. It cannot be obtained
ARTIFICIAL. in a concrete form. A strong heat decomposes it.

Acid of wood. With earthy and alkaline bases it forms peculiar salts, whose general properties have not been minutely enquired into. As the properties of the acid obtained from a considerable variety of woods have proved to be the same, it is presumed that all woods contain this common acid, or at least that combination of principles which constitutes its base.

Observations
 on the effect of
 nitrous acid
 upon vegetable
 bodies.

Since the acidification of combustible substances is evidently produced by the application or combination of vital air; and as, in all the operations of chemistry, effects may be produced by one mode of combination, which are impracticable in others; it becomes necessary, in chemical researches, to try every means which can be devised. Few vegetable acids are artificially produced by the direct application of vital air to the principles of that class of bodies; but many experiments have been made by abstracting the nitrous acid from vegetables by distillation. This acid, as we have frequently had occasion to observe, is very easily decomposed, when applied to combustible bodies, which attract its vital air, and disengage either nitrous or phlogisticated air, as we have explained in our chapter upon that acid. It has likewise been observed, in various parts of the present section, that this acid, when repeatedly distilled from gums, mucilages, sugar, the acids of tartar, of apples, and of gall, produces the peculiar acid which has been called the acid of sugar; and, if the abstraction be repeated too often, the acid
 of

of sugar itself is converted into fixed air. From this view of the subject, together with other facts, it has been inferred, that a greater or less proportion of vital air, united with one general principle abundantly existing in charcoal, whether this principle be inflammable air or not, produces all the various acids of vegetables. Thus tartar, which is the least acidified, is said to become converted into the acid of apples by treatment with nitrous acid. The acid of apples, by a continuance of the operation, becomes converted into acid of sugar, or acid of sorrel, which are the same thing. The same process, further continued, affords vinegar*, which comes over. Hence it should seem that, according to the greater progress of the operation of combustion, or the combination of vital air with the base (which at the same time, according to the ancient theory, is supposed to be more dephlogisticated), the acids of tartar, of apples or unripe fruit, of sorrel or sugar, of vinegar, and, lastly, of fixed air, are produced. In this order of proceeding, the acids become more and more perfect, and less easily decomposable: and on this account probably it is, that attempts to reverse the processes have not hitherto been attended with much success.

VEGETABLE
ACIDS:
ARTIFICIAL.

The progress
of acidification
in vegetable
bodies.

Since the discovery that the acid of sugar does not differ from that of sorrel but in containing a small proportion of alkali, the procuring of the former in the expensive way of distillation with nitrous acid, is

Difference between the acids of sugar and sorrel.

* See Scheele's Essays, English translation, page 385; and the Journal de Physique for January 1788, page 59.

become

VEGETABLE ACIDS : become unnecessary. We shall, nevertheless, describe
 ARTIFICIAL. the process here, as an example of that method of
 operating.

The process
 for converting
 sugar into an
 acid.

Three ounces of strong nitrous acid, whose specific gravity was nearly 1.567, were mixed in a tubulated retort with one ounce of the finest sugar in powder. Much nitrous air escaped in red fumes, formed by combination with the vital air of the atmosphere. A receiver was then adapted, and the liquor gently boiled. As soon as the mixture had acquired a dark brown colour, three additional ounces of nitrous acid were added, and the boiling was continued until the coloured and fuming acid had entirely disappeared. The liquor being then poured out, afforded small prismatic crystals by cooling, which are the acid of sugar. The lixivium, being again treated in the same manner with two ounces of nitrous acid, afforded an additional portion of acid of sugar by cooling; and the remaining glutinous liquor, treated at different times with small quantities of nitrous acid, amounting in the whole to two ounces, and evaporated to dryness, afforded a saline mass : and, lastly, the whole was depurated by repeated solutions and crystallizations in water. In this way, with three parts of sugar, and thirty of nitrous acid, the quantity of one part of acid of sugar is obtained.

Observation.

The above process is taken from Bergman : but it may be observed that weak nitrous acid, or common aqua fortis, will answer the purpose as well as the concentrated acid ; and that, where it is not an object to collect the acid which comes over, there will be no need of any receiver, or other apparatus, except a

matrass, or Florence flask, to perform the operation in a chimney where there is a proper draught of air to carry off the acid fumes.

VEGETABLE
ACIDS:
ARTIFICIAL.

The acid of camphor * is produced by distilling the nitrous acid eight successive times from camphor. It is of a concrete crystalline form, of a bitter taste, and reddens the tinctures of violets and turnsole. It differs from the acid of sugar in not separating lime from the marine acid. With vegetable alkali it forms a salt in regular hexagons; with mineral alkali, a salt in irregular crystals; with volatile alkali, prismatic or needle-formed crystals; and with magnesia, a pulverulent soluble salt. It dissolves several metallic substances. But subsequent enquiries are wanting to establish the peculiar nature and properties of this acid.

Acid of camphor.

By distilling four times its weight of nitrous acid from cork, a yellowish thick acid matter is obtained, which is soluble in water, and has an austere bitterish taste. It does not crystallize, but becomes consistent like wax by evaporation; is soluble in ardent spirit; forms deliquescent salts with the earths and alkalis; and has as strong an attraction for lime as the acid of sugar †.

Acid of cork.

* Kofegarten, *Nouv. de la Republ. des Lettres*, Année 1785. Nos. 42 and 44; quoted by Fourcroy, *Elem. Chem.* iv. 104, edition of 1789.

† Brugnatelli, in the *Journal de Physique*, August 1787; or *Grell's Annals* for the same year.

CHAP. VI.

ON THE DESTRUCTIVE DISTILLATION OF VEGETABLE
SUBSTANCES.

VEGETABLE
PRODUCTS
BY FIRE.

Destructive
distillation.

IN the foregoing chapters we have occasionally treated of the decomposition of vegetables by destructive distillation, and have described the volatile products it affords. As the immediate principles of organized substances are for the most part very compounded, and the extreme temperature produced in this method tends to reduce them to their primary component parts, it is evident that very little can be learned in this way concerning that on which the various properties of those substances depend. But as the chemist ought to neglect none of the methods he possesses of producing changes in bodies, this process may have its use when compared with others, and more especially when we shall have arrived at that knowledge of the first principles of organized substances, which from a variety of facts, and the late rapid progress of chemistry, we have reason to hope for. We shall therefore proceed to describe the general phenomena of destructive distillation.

This process consists merely in exposing any organized substance to heat in a retort, placed in a reverberatory furnace. The ancient chemists, who paid no attention to the elastic products, except so far as their

their expansive force impeded their operations, usually drilled a small hole in the upper part of the receiver for their escape. Modern chemistry proceeds in a more scientific manner, by using the pneumatic apparatus, fig. 21. The first product which comes over in the distillation of vegetables, is a watery fluid, containing acid and odorant principles. In proportion as the destruction of the vegetable proceeds, the phlegm becomes deeper coloured, and more saline. Next follows a coloured oil, which becomes of a darker hue as the distillation proceeds, and varies greatly according to the nature of the plant; for it consists chiefly of the essential oil, which comes over in a foul state, and differs in its fixity, density, fusibility, and all its other properties according to the nature and quantity of the essential oil which predominates in it. All the products obtained in this way have a peculiar burned smell, which chemists distinguish by the name of empyreumatic. If the vegetable contain volatile alkali, or its component parts, this substance usually sublimes when the oil comes over. The elastic fluids which pass into the apparatus of inverted vessels are chiefly inflammable air, or fixed air, or a mixture of both (probably in combination), which is heavier than pure inflammable air, and burns with a lambent blue flame, instead of detonating like that elastic fluid. The heat must be very gradually raised, and the receivers changed from time to time, in this method of decomposition; otherwise the products which come over will be confounded together, and the results will of course be more fallacious than they would otherwise have been. The fixed residue consists of charcoal, a small

VEGETABLE
PRODUCTS
BY FIRE.

Decomposition
of vegetables
by fire.

VEGETABLE
PRODUCTS
BY FIRE.

Empyreumatic
oils.

small portion of alkali, and a very minute quantity of earth.

The empyreumatic oils which come over in these distillations, may all be rendered colourless, and soluble in ardent spirit by rectification. In this manner it appears therefore that the fixed oils of vegetables are converted into volatile or essential oils; from which, as well as from other circumstances, it is rendered probable that these oils differ from each other only in the proportion of their component parts.

Charcoal :

The black, sonorous, brittle, light substance, called charcoal, usually retains the figure of the vegetable from which it was produced, unless the greater part of the vegetable consisted of fluids, which, in their dissipation, destroy the connection of the more fixed parts. In the latter case the quantity of charcoal is much less than in the former. It is a singular fact, that this substance, when well burned, is a perfect conductor of electricity; though the electric matter is not conveyed at all through wood which is simply baked or dried. The charcoal of oily or bituminous substances is of a light pulverulent form, and rises in foot. This charcoal of oils is called lamp-black.

—conducts
electricity :

—resists heat,
and absorbs
elastic fluids :

Charcoal resists the most violent heat in closed vessels. If it be ignited, it absorbs elastic fluids with great avidity as it cools; and it retains the property if cooled by immersion in mercury, the absorption being equally considerable when it is afterwards exposed to the air.

—exceedingly
combustible.

The disposition to be burned, which in the ancient theory is supposed to consist in the giving out of phlogiston, and in the modern theory in the absorption

forption of vital air, is so great in charcoal, that it performs the reverse of combustion with a great variety of substances. Thus it converts the vitriolic acid into vitriolic air, by augmenting the proportion of sulphur; and it is strongly acted on by the nitrous acid, much nitrous air being extricated at the same time. The rapidity with which the nitrous acid acts upon perfectly dry charcoal, has been already mentioned. In either of these processes, the acid either combines suddenly with the phlogiston of the charcoal, or the vital air of the acid combines with the charcoal itself, considered as a simple substance.

VEGETABLE
PRODUCTS
BY FIRE.

Charcoal.

Page 171.

The most violent combustion of nitre with charcoal, in which the acid is entirely decomposed, and gives out phlogisticated air, may be explained in the same way by each theory.

Alkalis dissolve charcoal in the dry way; and liver of sulphur combines very readily with it, either in the dry or humid way. All the metallic substances hitherto known, are less combustible than charcoal, and consequently are revived, or reduced to the metallic state, by being heated with this substance. This, in the ancient theory, denotes that all the metals attract phlogiston more strongly than charcoal does; but in the new theory the effect is ascribed to the stronger attraction of charcoal, which deprives all metallic calces of the vital air which combined with them during their calcination.

Solubility of
charcoal.

Revivification.

An important consequence seems to follow from this circumstance; namely, that there may exist many metallic substances whose combustibility may be greater than that of charcoal; and which conse-

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quently

VEGETABLE
PRODUCTS
BY FIRE.

quently are unknown to us as such, because we possess no means of reducing them. Thus the alkalis and earths may consist of peculiar combustible or metallic substances, either dephlogisticated, or combined with vital air, by an union which the art of chemistry has not yet found means to break.

Combustion of
charcoal.

When charcoal is exposed to heat in open vessels, it burns with a light flame, nearly transparent, emitting very little light, and no smoke. The residue consists of a small quantity of ashes, which contain fixed alkaline and neutral salts. The fixed vegetable alkali

Residual salts.

is obtained from the ashes of various plants, under the name of pot-ash or pearl-ash, and is not easily purified from the neutral salts it may be contaminated with. Mineral alkali is obtained by incineration only from marine plants. The neutral salts found in the ashes of vegetables are vitriolated tartar, Glauber's salt and selenite, common salt, and salt of Sylvius. Calces of iron and of manganese, with an earthy substance, compose the insoluble residue. What this earthy substance is has not been determined; but it most probably consists of some insoluble earthy salt, such as phosphorated lime.

Spontaneous
combustion of
coaly matter
and oil.

A variety of instances of combustion have been observed to take place in the mixture of coaly matter with oils. Whether these arise from the operation of vital air previously absorbed from the atmosphere by the coal, or from the decomposition of water which is present in these experiments, or from a mere change of capacity, by which the new combination may give out heat enough to ignite the mass, must remain for future researches. The subject however is so generally

generally interesting, as to admit of an enumeration of some of the facts in this place. The following are taken from M. Bucholz's paper *, in vol. i. of the Chemical Annals, by Dr. Hopson in his General System of Chemistry. SPONTANEOUS INFLAMMATION.

On occasion of a frigate that in 1781 took fire in the port of Cronstadt, just as she was preparing to set sail, though no fire had been made in her for five days before, M. Georgi, of the imperial academy of Petersburg, made a great number of experiments. He impregnated gradually three pounds of Prussian lamp-black with five pounds of boiled hemp-feed oil; and after having left the mixture exposed to the air for about five hours, wrapped it up in a coarse linen cloth. This mass, after having lain in a chest for about sixteen hours, yielded a very offensive and seemingly putrid smell, not much unlike that of burning oil. Some parts of the mass grew warm, then hot, and emitted a considerable quantity of vapour. These vapours were watery, and by no means inflammable. Within about eighteen hours after the packet was made, some part of it, growing warm, exhibited smoke, and immediately afterwards was actually ignited. The same happened at two or three other places, but others were scarcely warm. The fire spread very slowly, and emitted a thick stinking smoke. M. Georgi then taking the mass out of the chest, and laying it on a stone floor, where it was more exposed

Narrative.

* As the Journal de Physique is in more hands in this country than the German Annals of Crell, the reader is informed that the whole of the paper of M. Georgi is to be found, in French, in that Journal for July 1782.

SPONTANE-
OUS INFLAM-
MATION.

Narrative.

to the air, a flame of about six inches high arose, with much smoke; whenever any openings or crevices were made in the mass, they threw out vapours, which soon after took fire. The mass being thrown upon the floor broke in pieces, and a brisk flame arose on a sudden, about three feet in height, which soon ceased; when the materials continued to glimmer at first with smoke, and afterwards without, for the space of six hours. The whole was consumed in about eight hours. The ashes, which were grey, weighed when cold eight ounces and a half.

In another experiment, exactly similar to this as to what relates to the mixture and quantity of the materials, the inflammation did not take place for forty-one hours after the oil had been imbibed by the lamp-black. In general, the inflammation took place much sooner in fine clear days than in rainy weather.

In another experiment he impregnated three pounds of Russian lamp-black with three pounds of hemp-seed oil unboiled, and the inflammation took place in the space of nine hours.—Twelve ounces of fine German lamp-black, mixed with twenty-four ounces of boiled hemp-seed oil, did not grow warm till after seventy hours were elapsed. It then became gradually hotter, and emitted vapours, which were not inflammable. The re-action of the materials lasted about thirty-six hours, in which time the heat was sometimes greater, and sometimes less, till at last it ceased entirely. He made a great many more experiments for the board of admiralty at Petersburg, of which the following are the results. The inflammation takes place much sooner when Russian lamp-black, which is coarse, greasy,

greasy, and heavy, is impregnated with the oil, than SPONTANEOUS INFLAMMATION.
when the German lamp-black, which is light and fine, or common wood foot, is employed for this purpose.

With regard to the oils, the inflammation only happens with drying oils, either boiled or crude. The proportion of the lamp-black to the oil differed greatly in these experiments: the lamp-black, or foot, took fire with $\frac{1}{10}$ $\frac{1}{3}$ $\frac{1}{3}$ equal parts, and even with twice the quantity of the oil. In general, the inflammation depended more upon the mode of mixing the ingredients than upon the quantity of them: and also, as M. Georgi often observed, upon the weather; for, in wet weather, the mass, after growing warm, became cold again.

A packet of hemp, of about thirty pounds weight, was impregnated with a mixture of three pounds of tallow and three pounds of hemp-seed oil, and put into a baker's oven, which was heated to 90° of Fahrenheit. On taking it out of the oven an hour afterwards it was hardly warm. In the space of an hour after this it began to smoke, and in another hour the spontaneous inflammation took place; when M. Georgi observed that it began about the surface, and not in the middle, of the mass. He attributed much to the high wind that blew on that day. The packet burned for the space of five hours, with a visible flame.

Subsequent to these experiments with hemp and flax, this ingenious philosopher made others with wool. He impregnated twenty pounds of wool with a mixture of two pounds of hemp-seed oil, and one of tallow. After having mixed the wool equally with oil, he put it into a small baker's oven, and kept it

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there

SPONTANE-
OUS INFLAM-
MATION.

Spontaneous
combustion of
wool with oil :

there for the space of an hour, after which he took it out, and sewed it up in a mat. The packet cooled by degrees, and remained in that state three days, at the expiration of which period the wool was found quite sound and entire, and the fat was so thoroughly imbibed by the wool that it was scarcely perceptible. On the same wool he now poured a pound of hempseed oil, and put it again into a baker's oven, of which the heat was 95° of De Lisle's thermometer. After remaining there an hour, it was tied up in a coarse linen cloth, and laid on some wood in the laboratory. A few hours after, the packet grew warm in some places, and emitted a slight smoke, which increased to that degree, that two hours afterwards a spontaneous inflammation took place. The fire glimmered slowly, but when the window was opened it burned for half an hour with a low flame. In the space of forty-four hours it ceased burning, when there remained two pounds and six ounces of coal, and two pounds of very fine ashes.

—of other substances.

He made a great many experiments besides, in which the spontaneous inflammation took place; such as sleeping cow hair and wool in oil, and then exposing them to a certain degree of heat, &c. from which may be drawn this general conclusion, viz. that oils, mixed either with vegetable or with animal substances, after they have parted with all their water, begin to take fire. The heat may either have been occasioned by an intestine motion, as is the case when oils are mixed with coarse lamp-black, or with black wad, where, by the internal heat, the whole of the fluid previously evaporates; the inflammation not taking place

place till the water is evaporated: or else when vegetable or animal substances are impregnated with oils, when the oil, in consequence of the great surface given it, parts with its water so much the sooner, and thus acquires a solid and substantial body with which it can take fire. This inflammation takes place, as Messrs. Hagemann and Geller have observed in Crell's Chemical Annals, 1784, p. 488, in the apothecaries' shops, in oils that are boiled till they are deprived of all their water.

SPONTANEOUS INFLAMMATION.

M. Georgi also roasted barley, groats, and rice; and he found, that the larger the grains are, the less they are disposed to take fire. Thus coffee roasted brown, and bound up in linen, did not kindle; the contrary to which however was the case with ground coffee, which took fire in three quarters of an hour, and continued spreading till half an ounce of ashes remained out of two pounds of coffee. In order to satisfy himself that it was only the size of the coffee berries that prevented the mutual action of the component parts, the abovementioned coffee was ground, and roasted again tolerably brown, and wrapped up in linen. In an hour after this the powder took fire.

Spontaneous inflammation of roasted grain:

Saw-dust of mahogany wood was roasted over a gentle fire till it was of a brownish hue, and kindled in a quarter of an hour after it had been wrapped up. Two pounds of saw-dust of fir wood, on account of the different size of the particles, became partly black in roasting, and partly white. After being wrapped up, it soon lost its heat, but an hour after the heat returned with smoke, when quickly it took fire.

—of roasted saw-dust.

SPONTANEOUS INFLAMMATION.

Spontaneous inflammation of malt.

In order to know whether the compression of vegetable substances, and the modification of the air by surrounding them with linen, were essential to the spontaneous inflammation, and whether a spontaneous inflammation would take place without the observance of this circumstance, M. Georgi roasted some barley coffee till it was brown, which he put into a shallow pot, without covering the latter entirely with its lid. After fourteen hours were elapsed, the warmth of the pot returned, and a smoke arose. There was no fire perceived in the dark; the inside of the pot however had a phosphoric appearance, and paper and bits of wood soon took fire; and a knife, upon being plunged into the mass, became red-hot. In twenty-four hours the fire was extinguished.

The following remark of M. Georgi is of the greatest importance. In the drying of malt, and in the roasting of other substances of a similar nature, the malt or other materials may take fire of themselves in a corner of the kiln a long time after the operation is finished, and that even in the open air; and, without giving any signs of accension except a trifling degree of smoke, burn for a considerable time, and do a great deal of mischief. From all that has been mentioned it appears, that the smaller kinds of grain, as well as flour, saw-dust, and other minutely divided and inflammable substances, when taken in considerable quantities, and united with oily matters, are capable of taking fire of themselves, under certain circumstances, in consequence of their being furcharged with inflammable particles, as well as of an intestine motion and mutual actions in their constituent parts,

by

by which the inflammable particles are disengaged. SPONTANEOUS INFLAMMATION.
 This is certainly a very remarkable, and hitherto not sufficiently investigated, property of many substances appertaining to the vegetable and animal kingdoms, the knowledge of which is very important for the farmer, manufacturer, and artist.

Mr. Lowitz and after him other chemists have observed a remarkable property in charcoal, by which it purifies various mucilaginous, saline, and other bodies *. The process consists in adding very pure charcoal, in fine powder, to the solution of the salt. The quantity required is in general considerable; and the saline matter is afterwards separated by the usual methods of chemistry, namely filtration, decantation, evaporation, or distillation, severally or jointly, as the nature of the subject may require. It has not been shewn in what manner the charcoal operates, whether by simply absorbing the mucilage, or by any process of the nature of combustion. If the latter should be probable, our attention should perhaps be directed to the air absorbed by the charcoal during its cooling from its first ignition.

Purification of
salts by charcoal.

* The papers of Mr. Lowitz are inserted in Crell's Journal, of which we have two volumes translated in English. A considerable portion of their contents is inserted in the Chemical Dictionary, art. Vinegar and Charcoal, in the Appendix.

C H A P. VII.

CONCERNING FERMENTATION IN GENERAL.

FERMENTA-
TION.

The spontane-
ous decomposition
of vegeta-
bles.

Three stages of
fermentation :

—vinous :

—acetous :

Page 459.

—putrid.

THE word Fermentation, in an enlarged sense, is used to denote that change of the principles of organic bodies, which begins to take place spontaneously as soon as their vital functions have ceased, and by which they are at length reduced to their first principles. This has been distinguished into three stages; the vinous or spirituous, the acid or acetous, and the putrid fermentation : which are so called from the principal products obtained during their action. All organized bodies are not subject to the three degrees of fermentation. It is ascertained almost beyond a doubt that the vinous fermentation takes place only in such bodies as contain saccharine juices. In this the most remarkable product is a volatile, colourless, light, inflammable fluid, which mixes with water in all proportions, and is called ardent spirit. The acetous fermentation is distinguished by the product known by the name of vinegar, which is the least destructible of the vegetable acids. It does not appear, however, that fermentation is absolutely necessary for the production of this acid, as there are other chemical means by which it may be obtained, or produced. In the putrid fermentation, bodies appear to be reduced into their most simple parts. Volatile alkali is the product

product which has been remarked as the chief in this process, and is no doubt produced by the combination of inflammable and phlogisticated air, which fly off together. The acetous, like the vinous fermentation, is confined to vegetable substances; but the putrefactive process is most eminently perceived in animal bodies. These either putrefy immediately; or, if the putrefaction be preceded by either of the other stages, their duration is too short to be perceived. It is considered as an established fact, that the three stages of fermentation always follow in the same order, in such bodies as are susceptible of them all; the vinous coming first, which is followed by the acetous and the putrefactive processes.

FERMENTATION.

Stages of fermentation.

The spontaneous decomposition of bodies is greatly retarded by extreme cold, by sudden drying of the parts, or by preservation in closed vessels. The two first circumstances necessarily retard the chemical effects, by depriving the parts of that fluidity which is almost indispensably necessary in chemical processes. It will easily be understood that the third circumstance will retard the spontaneous decomposition of bodies, when it is considered that the atmosphere itself is the solvent and receptacle of many of the component parts of bodies with which it is disposed to combine. In well-closed vessels, the parts of organized bodies which are disposed to fly off in the elastic state, are prevented from escaping; and such parts as might form new combinations, by absorbing either the contents or component parts of the atmosphere, are prevented for want of a free communication. The three conditions for the accomplishment of fermentation are,

Conditions or circumstances requisite to the progress of fermentation.

FERMENTA-
TION.

Vinous fermentation described, as it takes place in sugar and water.

Yeast.

Inflammable
spirit.

therefore, fluidity or moisture, moderate heat or a due temperature, and the access of air: and the fermentation will likewise be modified according to the various component parts of bodies.

In describing the vinous decomposition of vegetables, it will be of advantage to attend to that of mere sugar and water; the phenomena in these being more distinct, because less modified by foreign admixture. If a considerable quantity of water, holding in solution about one third of its weight of sugar, be exposed to the air at the temperature of about 70 degrees, after the addition of a small quantity of yeast, it soon undergoes a remarkable change. In the course of a few hours the fluid becomes turbid and frothy; bubbles of fixed air are disengaged, which rise and break at the surface. The disengagement becomes more and more abundant; mucilage is separated, part of which subsides to the bottom; and part, expanded into froth by the elastic fluid, forms yeast. During the course of several days, these effects gradually come to their height, and diminish again; after which they proceed very slowly, but are long before they entirely cease. The fermented liquor has no longer the sweet taste it had before, but becomes brisk and lively, with a pungent spirituous flavour. Its specific gravity likewise is considerably less than before; and, when exposed to distillation, it affords a light inflammable spirit. The quantity of ardent spirit which any fermented liquor will produce, is thought to follow some proportion of the change its specific gravity undergoes in fermentation; but the truth of this has not been clearly ascer-

ascertained *. Wine, cyder, and beer, are well-known **FERMENTA-
TION.**

It is usual to put fermented liquors into casks before **Acetous fer-
mentation.** the vinous fermentation is completely ended; and in these closed vessels it goes on for many months. But if the fermentative process be suffered to proceed in open vessels, more especially if the temperature be raised to 90 degrees, the acetous fermentation comes on. In this the vital part of the air is gradually absorbed; and the more speedily, in proportion as the surfaces of the liquor are oftener changed by lading it from one vessel to another. The usual method consists in exposing the fermented liquor to the air in casks, placed so that the sun may shine on them; which seems to be of advantage, by raising the temperature of the liquor. By this absorption of vital air, the inflammable substance becomes converted into an acid. If the liquid be then exposed to distillation, pure vinegar comes over, instead of ardent spirit.

When the spontaneous decomposition is suffered **Putrefaction.** to proceed beyond the acetous process, the vinegar gradually becomes viscid and foul; air is emitted, with an offensive smell; volatile alkali flies off; an earthy sediment is deposited; and the remaining liquid, if any, is mere water. This is the putrefactive process.

Though fermentation is much better understood at present, in consequence of modern researches into the nature of elastic fluids, than it formerly was, it still

* Richardson on Brewing.

**FERMENTA-
TION.**

The effect of
yeast in fer-
mentation.

Component
parts of ardent
spirit, &c.

remains an interesting object of research. It is not clearly ascertained what the yeast or fermented matter performs in this operation. It seems probable that the fermentative process, in considerable masses, would be carried on in succession, from the surface downwards; and would perhaps be completed in one part of the fluid before it was perfectly begun in another part, if the yeast, which is already in a state of fermentation, did not occasion the process to begin in every part of the fluid at once. Much remains to be done towards ascertaining the arrangement and quantity of the component parts of ardent spirit: and the theory of fixed air, with the identity of inflammable airs, must be ascertained, before any decided reasoning can be adopted on this head. It seems however that inflammable air, in combination with fixed air in certain proportions, forms ardent spirit; that a greater proportion of vital air converts it into vinegar; and that, in the putrefactive process, the inflammable air, the fixed air, and the vital air, are separated from each other, and fly off in the elastic state.

Tartar.

In the fermentation of wine, the tartar, which probably existed for the most part ready formed in the juice of the grape, is separated, and exhibits the properties which have been already described in treating of that substance.

Bread.

The fermentation of bread by leaven is thought to be of a different nature from the vinous fermentation. In this the mucilage of the corn is not previously brought into the saccharine state. It quickly becomes four, if the process be not stopped by baking; in which particular, the fermentation seems to be of the

the acetous kind. The development of fixed air divides the dough into thin parts, which are more effectually and better baked than they could have been in the solid consistent mass. When bread is fermented by means of yeast, the process appears to be of a saccharine or vinous nature.

FERMENTA-
TION.

Bread.

C H A P. VIII.

CONCERNING VINOUS FLUIDS AND ARDENT SPIRITS.

VINOUS
FLUIDS.

The making of
wine from
grapes.

FROM the habits of society, the making of wine, beer, and ardent spirits, is become an object of considerable importance. Wine is the expressed juice of the grape which has undergone the first stage of fermentation. In this, which in general appears to be the best kind of fermented liquor, there are great differences, which depend no less on the kind and quality of the fruit than on the process of manufacturing. If the fruit be gathered unripe, the juice will abound with acid, and the wine will be thin and sharp; but, if the fruit be ripe, it will contain much saccharine juice, and the wine will be sweeter. If the wine be casked in an early stage of the fermentation, much of the sugar will remain undecomposed, and the wine will be sweeter on that account, especially if the fermentation be checked by a considerable degree of cold; but, on the contrary, when the progress of the fermentation is only impeded by the coercion of the vessel, which prevents the escape of the fixed air, a slight increase of temperature, such as that of a room in a dwelling-house compared with the temperature of a cellar, will cause it to proceed with great rapidity as soon as the vessel is opened. Wines in this state are very brisk and lively, from the predominating acidity of the fixed air, which is hastily disengaged.

Beer

Beer is the wine of grain. Malt is usually made of VINOUS
FLUIDS.
barley. This grain is steeped for two or three days in water till it swells, becomes somewhat tender, and tinges the water of a bright reddish brown colour. The malting of
barley :

The water being then drained away, the barley is spread about two feet thick upon a floor, where it heats spontaneously, and begins to grow, by first shooting out the radicle. In this state the germination is stopped, by spreading it thinner, and frequently turning it over for two days; after which, it is again made into an heap, and suffered to become sensibly hot, which usually happens in little more than a day. Lastly, it is conveyed to the kiln, where, by a gradual and low heat, it is rendered dry and crisp. This is malt; and its qualities differ according as it is more or less soaked, drained, germinated, dried, and baked. In this, as in other manufactories, the intelligent operators often make a mystery of their processes, from views of profit; and others pretend to peculiar secrets, who really possess none.

Indian corn, and probably all large grain, require —of Indian
corn.
to be suffered to grow into the blade, as well as root, before it is fit to be made into malt. For this purpose, it is buried about two or three inches deep in the ground, and covered with loose earth; and in ten or twelve days it springs up. In this state it is taken up and washed, or fanned, to clear it from its dirt, and then dried in the kiln for use.

Beer is made from malt previously ground, or cut in Brewing of
beer.
pieces by a mill. This is placed in a tun, or tub, with a false bottom; hot water is poured upon it, and the whole stirred about with a proper instrument. The

VINOUS
FLUIDS.

Brewing of
beer.

temperature of the water in this operation, called mashing, must not be equal to boiling; for in that case the malt would be converted into a paste, from which the impregnated water could not be separated. After the infusion has remained for some time upon the malt, it is drawn off, and is then distinguished by the name of sweet wort. By one or more subsequent infusions of water, a quantity of weaker wort is obtained, which is either added to the foregoing, or kept apart, according to the intention of the operator. The wort is then boiled with hops, which give it an aromatic bitter taste, and are supposed to render it less liable to be spoiled in keeping; after which, it is cooled in shallow vessels, and suffered to ferment, with the addition of a proper quantity of yeast. The fermented liquor is beer; and differs greatly in its quality, according to the nature of the grain, the malting, the mashing, the quantity and kind of the hops and the yeast, the purity or admixtures of the water made use of, the temperature and vicissitudes of the weather, &c.

Metheglin and
koumiss.

Besides wine and beer, which are made immediately from vegetables; other fermented liquors, containing ardent spirit, are made from honey and from mare's milk. The former is called metheglin; and the latter, which is made by the Tartars, koumiss*. This last is made by agitating the milk, at the time when its parts begin to separate, by a fermentation productive of a peculiar acid, called the acid of milk, hereafter to be described.

* Grieve, in the Edinburgh Transactions, vol. i. p. 181.

In order to obtain ardent spirit, nothing more is necessary than to expose wine, beer, or any other fermented vinous liquid, to distillation; and the product which comes over is the ardent spirit itself, contaminated with essential oil. If this be rectified by a second distillation, it becomes much purer. The most volatile part rises first, and is of a less specific gravity than that which comes over afterwards.

ARDENT
SPIRIT.

Product of vinous liquors by distillation.

The residue, after the distillation of ardent spirit from wine, is of a deep colour, a rough acid taste, and deposits crystals of tartar. The colouring matter is soluble in ardent spirit. So that it appears, from this imperfect analysis, that wine consists of water, ardent spirit, colouring matter of a resinous nature, sugar, tartar, and tartareous acid, and an aromatic principle.

Residue.

The strength or purity of ardent spirit is ascertained from its specific gravity; for the addition of water renders it heavier. According to M. Bories, whose Memoir, published at Montpellier in the year 1774, obtained the prize proposed by the states of Languedoc in 1772, the specific gravity of rectified ardent spirit, repeatedly poured on dry salt of tartar till it would no longer dissolve or liquefy it, was found by many experiments to be as follows:

Strength of ardent spirit determined by M. Bories.

$$\text{Reaumur's Therm.} + 10^{\circ} = 820 \frac{2900}{3033}$$

$$15^{\circ} = 817 \frac{65}{3033}$$

$$20^{\circ} = 813 \frac{2284}{3033}$$

The specific gravities of mixtures, by measure, of the foregoing spirit with distilled water, were as follows:

112

Tempe-

ARDENT SPIRIT.	Temperature + 15° Reaumur.				Specific gravity	817	$\frac{65}{3035}$
	Spirit	to	Water	o			
Specific gravi- ties of various mixtures of wa- ter and spirit.	9	—	1	—	—	844	$\frac{3580}{3035}$
	8	—	2	—	—	869	$\frac{4705}{3035}$
	7	—	3	—	—	893	$\frac{1805}{3035}$
	6	—	4	—	—	915	$\frac{925}{3035}$
	5	—	5	—	—	934	$\frac{3610}{3035}$
	4	—	6	—	—	951	$\frac{3605}{3035}$
	3	—	7	—	—	965	$\frac{1925}{3035}$
	2	—	8	—	—	976	$\frac{1320}{3035}$
	1	—	9	—	—	987	$\frac{715}{3035}$
	0	—	10	—	—	1,000	

Observations.

Strongest ar-
dent spirit by
mere distilla-
tion.

Upon the above experiments, which are among the most accurate we possess*, it may be observed, that the first term, or pure spirit, ought to be obtained with an alkali perfectly mild, or saturated with fixed air; because, otherwise, solution and combination of the alkali with the spirit might take place. By distillation of twenty measures of the best ardent spirit of the shops, whose specific gravity was 0.836 over a lamp in glass vessels, I found the first measure which came over had a specific gravity of 820, at the temperature of 71° Fahrenheit; which answers to $17\frac{1}{2}$ of Reaumur. This is the strongest spirit mere distillation can afford. When strong ardent spirit is added to water, a considerable heat is produced, a few bubbles of air are emitted, the mixture contracts in its dimensions, and acquires a greater specific gravity than would have been deduced by computation.

* See a very valuable set of experiments on this subject by Mr. Gilpin; of which Dr. Blagden has made a report in the Phil. Trans. lxxx. 321. These are amply tabulated in the Transactions for 1794, and an abstract of the results is given in the Chemical Dictionary, Art. Spirit, ardent.

It is by no means an easy undertaking to determine the strength or relative value of ardent spirit, even with sufficient accuracy for commercial purposes.—The following requisites must be obtained before this can be well done: The specific gravity of a certain number of mixtures of ardent spirit and water must be taken so near each other, as that the intermediate specific gravities may not perceptibly differ from those deduced from the supposition of a mere mixture of the fluids: the expansions, or variations of specific gravity, in these mixtures, must be determined at different temperatures: some easy method must be contrived of determining the presence and quantity of saccharine or oleaginous matter which the spirit may hold in solution, and the effect of such solution on the specific gravity: and, lastly, the specific gravity of the fluid must be ascertained by a proper floating instrument with a graduated stem, or set of weights; or, which may be more convenient, with both.

ARDENT
SPIRIT.

Requisites or desiderata to ascertain the strength of spirit.

The strength of brandies in commerce is judged by the phial, or by burning. The phial proof consists in agitating the spirit in a bottle, and observing the form and magnitude of the bubbles, which are larger the stronger the spirit. These probably depend on the solution of resinous matter from the cask, which is taken up in greater quantities, the stronger the spirit. It is not difficult however to produce this appearance, by various simple additions to weak spirit.—The proof by burning is also fallacious; because the magnitude of the flame, and quantity of residue, in the same spirit, vary greatly with the form of the vessel it is burned in. If the vessel be kept cool, or suffered to become hot,

Phial proof.

Proof by burning.

ARDENT
SPIRIT.

if it be deeper or shallower, the results will not be the same in each case. It does not follow, however, but that manufacturers and others may in many instances receive considerable information from these signs, in circumstances exactly alike, and in the course of operations wherein it would be inconvenient to recur continually to experiments of specific gravity.

Characters and
component
parts of ardent
spirit:

The most remarkable characteristic property of ardent spirit is its solubility or combination in all proportions with water; a property possessed by no other combustible substance. When it is burned in a chimney which communicates with the worm-pipe of a distilling apparatus, the product which is condensed is found to consist of water, which exceeds the spirit in weight about one eighth part. If ardent spirit be burned in closed vessels with vital air, the product is found to be water and fixed air. Whence it is inferred, that ardent spirit consists of inflammable air, united either to fixed air, or its acidifiable base; and that the vital air, uniting on the one part with inflammable air, forms water; and, on the other, with the base of the fixed air, and forms that acid*.

its uses and
combinations.

A considerable number of the uses of this fluid, as a menstruum, have already passed under our observation. The mutual action between ardent spirit and acids, produces a light, volatile and inflammable oil, called ether. Pure alkalis unite with spirit of wine, and form alkaline tinctures. Few of the neutral salts unite with

* For an account of these experiments, and the precautions necessary to be attended to in making them, consult the Memoirs of M. Lavoisier, in the Memoirs of the Royal Academy at Paris for 1781 and 1784.

this fluid, except such as contain the volatile alkali. The mild fixed alkalis, or combinations of alkali and fixed air, are not soluble in it. From the strong attraction which exists between ardent spirit and water, it unites with the last in saline solutions, and in most cases precipitates this salt. This is a pleasing experiment, which never fails to surprise those who are unacquainted with chemical effects. If, for example, a saturated solution of nitre in water be taken, and an equal quantity of strong spirit of wine be poured upon it, the mixture will constitute a weaker spirit, which is incapable of holding the nitre in solution; it therefore falls to the bottom instantly, in the form of minute crystals. Among the neutral salts which are soluble in spirit of wine, the deliquescent earthy salts stand first. Most ammoniacal salts are soluble in this menstruum; and in general it combines more readily with such as have their acid less adherent to the neutralizing base.

ARDENT
SPIRIT.

Mutual action
of ardent spirit
and salts:

Sulphur does not appear to be acted on more —and sulphur: strongly by ardent spirit than by water. If sulphur in sublimation meet with the vapour of spirit of wine, a very small portion combines with it, which communicates an hepatic odour to the fluid. The increased surface of the two substances appears to favour the combination.

Phosphorus is sparingly soluble in ardent spirit, but —and phosphorus. in greater quantity by heat than in the cold. The addition of water to this solution affords an opaque milky fluid which gradually becomes clear by the subsidence of the phosphorus.

Earths seem to have scarce any action upon ardent —and earths. spirit.

ARDENT
SPIRIT.

spirit. Quick-lime however produces some alteration in this fluid, by changing its flavour, and rendering it of a yellow colour. A small portion is probably taken up.

Spirituous solu-
tions.

Soaps are dissolved with great facility in ardent spirit, with which they combine more readily than with water. None of the metals, nor their calces, are acted upon by this fluid. Resins, essential oils, camphor, bitumen, and various other substances, are dissolved with great facility in ardent spirit, from which they may be precipitated by the addition of water.

CHAP. IX.

CONCERNING THOSE INFLAMMABLE FLUIDS WHICH
ARE PRODUCED BY THE ACTION OF ACIDS UPON
SPIRIT OF WINE, AND ARE KNOWN BY
THE NAME OF ETHER.

WHEN strong vitriolic acid is poured upon an equal measure of rectified spirit of wine, the two fluids unite together, with a hissing noise and the production of heat, at the same time that a fragrant vegetable smell is emitted, resembling that of apples. It is more advantageous, however, to add the acid in so gradual a manner as to produce little or no heat. If the mixture be made in a retort, and then exposed to distillation by a well-regulated heat in a sand-bath, a large receiver being adapted, and kept cool by immersion in water, or by the frequent application of wet cloths, the volatile products may be safely condensed. Spirit of wine of a fragrant smell comes over first, and is followed by the ether, as soon as the fluid in the retort begins to boil. At this period the upper part of the receiver is covered with large distinct streams of the fluid, which run down its sides. After the ether has passed over, volatile sulphureous acid arises, which is known by its white fumes and peculiar smell. The receiver must now be removed, and another substituted in its place, care being taken to avoid breathing the penetrating fumes of the acid.

The

ETHER.

The making of
vitriolic ether.

ETHER. The fire must at the same time be moderated, because the residue in the retort is disposed to swell. A light yellow oil, called sweet oil of wine, comes over after the ether, and this is succeeded by black and foul vitriolic acid. The residue varies in its properties, according to the management of the heat. If the fire be much increased towards the end of the process, the volatile vitriolic acid which comes over will be mixed with vinegar. If the remaining fluid contained in the retort, after the ether has passed over, be not urged farther, it may be made to afford more ether by the addition of one-third of very strong ardent spirit; and this may be repeated successively, until near twice the quantity of the spirit originally made use of has been added.

Rectification. Ether of the first distillation is not pure, but contains spirit of wine and sulphureous acid, which may be separated by the addition of a fixed alkali, and rectifying with a gentle heat. In this rectification, as in all others, the first products are the purest.

Characters. Vitriolic ether is one of the lightest and most volatile of all dense and unelastic fluids. Its dissipation into the air is so sudden as to produce an extreme degree of cold. It is highly inflammable, and burns with a more luminous flame, and emits more smoke, than ardent spirit.

Solubility in water. About ten times its weight of water is sufficient to dissolve it. A small proportion of water renders unrectified ether more pure, because it combines with the ardent spirit and acid it may contain; but there is reason to think, on the other hand, that the ether dissolves, and combines with part of the water.

Little

Little is known of the action of this fluid upon saline substances. Lime and fixed alkalis do not seem capable of uniting with it. Caustic volatile alkali combines with it in all proportions; vitriolic acid unites with it, and extricates heat, and from this combination sweet oil of wine may be obtained by distillation. Nitrous acid effervesces with ether, and renders it more oily. It dissolves camphor very plentifully.

ETHER.
Combinations
of vitriolic
ether.

The nitrous acid acts very rapidly and powerfully upon ardent spirit, with which it forms a combination, possessing properties similar to those of the vitriolic ether. The combination takes place without the assistance of heat, and with such facility, that it is even necessary to add the acid by degrees, and to use management for the purpose of preventing an explosion, which might arise from the heat generated by the mixture. For this purpose, six ounces of highly rectified spirit of wine are put into a bottle capable of containing a pound of water, and immersed in a tub of very cold water, in which it will be advantageous to put three or four pounds of ice broken small. Upon the spirit in this situation, and kept continually agitated, four ounces of spirit of nitre, of the specific gravity of 1.5, are to be poured, in four or five successive portions. As soon as the mixture is completed, the bottle must be closed with a good cork, secured with leather and packthread, or wire; and the whole must be left in a place where it may remain undisturbed; no other attention being necessary than that of renewing the water, from time to time, as it may become heated. In the course of two or three hours,
the

Method of pre-
paring nitrous
ether.

ETHER.
 Methods of
 preparing ni-
 trous ether.

the transparency of the fluid becomes troubled by an infinity of drops of ether, which are disengaged from every part of its volume. This ether gradually rises to the surface; and at the end of twenty-four hours it may be separated from the rest of the liquor by means of a funnel. In opening the phial, it is necessary first to pierce the cork with a pointed instrument, in order that a quantity of elastic fluid may escape, which might otherwise suddenly follow the cork, and carry part of the fluid along with it. The quantity of ether obtained in this manner will be about four ounces.

Characters.

Nitrous ether in this state resembles vitriolic ether in its smell, but it is stronger and less agreeable. Its colour is a light orange; and a portion of the fluid takes the elastic form, and escapes with effervescence whenever the bottle, which contains it, is opened. This ether appears to contain a portion of uncombined acid, upon which these phenomena probably depend. It must be rectified with a small addition of alkali, during which operation it loses near half its weight. The rectified nitrous ether burns with a flame rather more luminous than that of vitriolic ether, at the same time that it affords a somewhat larger portion of smoke, and leaves a black trace behind it. In other respects it seems nearly to resemble the vitriolic ether.

Nitrous ether may be made with less danger, if the acid be diluted, and the quantity of spirit duly proportioned. It may also be had by distillation of a mixture of the two fluids, in the same manner as the vitriolic ether; but in this case it is requisite that the receiving vessels should be uncommonly large, and
 that

that every precaution should be taken to prevent their flying in pieces by the force of the elastic product which escapes; and, upon the whole, it does not seem probable that any ordinary degree of precaution would be sufficient to insure the operator from danger in this distillation. One very essential circumstance consists in using the acid in a diluted state.—Nitrous ether has also been made by less direct processes. If a due proportion of nitre and vitriolic acid be successively put into a tubulated retort, the nitrous acid begins to be disengaged; and, if spirit of wine be added to this mixture, nitrous ether comes over. Some degree of precaution is necessary in this process; and it might be doubted whether part of the ether which comes over might not have been formed by the vitriolic acid, if most of the difficulties were not removed by the use of the apparatus, fig. 22. If the tube E be immersed in a bottle containing highly rectified spirit of wine, and the nitrous acid be distilled from a quantity of nitre equal in weight to twice the spirit of wine, together with as much concentrated vitriolic acid as is equal to half the weight of the nitre; the first receiver D will, at the end of the operation, contain fuming nitrous acid; the remote bottle E will contain an ethereal liquor; and the residue will be vitriolated tartar. The ethereal spirit of wine may then be distilled, and the first two-thirds of the product reserved. This reserved product must be distilled with one-fifth of its weight of smoking nitrous acid, added by degrees to the liquor in a tubulated retort, by means of a long-necked funnel. Two-thirds of this product only are to be taken; which, being recti-

ETHER.
Methods of
preparing ni-
trous ether.

ETHER.
 Nitrous ether.

fied from pot-ash, afford at first a quantity of very pure nitrous ether, equal to about one twelfth of the spirit made use of; and three-fourths of the rest being distilled over consist of a less perfect ether, or mineral anodyne liquor. The residues of the distillations consist of dulcified spirit of nitre *.

It is proper, even here, to take notice that all mixtures of the nitrous acid and ardent spirit require to be made very gradually, and with great caution, for fear of explosions.

The residue, after distillation of nitrous ether, is found, in some proportions of the materials and management of the process, to contain no nitrous acid, but an imperfect vinegar, and the acid of sugar or sorrel.

Method of
 preparing ma-
 rine ether.

The marine acid cannot be combined with spirit of wine in the direct way. There are many indirect methods, which consist in applying the dephlogisticated or aerated marine acid to ardent spirit. If to four ounces of common salt, and two ounces of pulverized manganese, there be added two ounces of concentrated vitriolic acid, and six ounces of the purest ardent spirit, and the whole be exposed to distillation by a gentle heat, the marine acid will first rise, somewhat changed; and, after a considerable portion has passed over, it must be poured back upon the residuum, and distilled afresh. In this distillation, nearly the half which first comes over will be dulcified spirit of salt; and the greatest part of the other half, marine ether, which may be separated from the rest by the addition of water.

* De la Planché, quoted by Fourcroy, iv. 252.

Marine ether is very transparent and volatile, and has nearly the same smell as the vitriolic ether. It burns like that fluid, and affords a smoke, with a suffocating smell.

ETHER.

It is doubted whether any ethereal fluid can be obtained by the direct union of acetous acid and ardent spirit. If equal parts of the strongest acetous acid and ardent spirit be mixed together, and kept for some days in a well-stopped glass, and the mixture be then exposed to distillation by a gentle heat, the first half which comes over will, it is said, consist of an ethereal fluid, from which the ether may be separated by the addition of a sixteenth part of vegetable alkali dissolved in four times its quantity of water. The ether immediately rises to the top, and commonly amounts to one half of the quantity of the ardent spirit made use of. To the vinegar that remains in the retort half the quantity of ardent spirit may be added, by which still more of the ether may be obtained. The most certain and incontrovertible method, however, appears to consist in forming the union between the spirit and acid by indirect means. This may be done by decomposing some acetous salt, by the addition of a mineral acid, while ardent spirit is present. Thus, if an ounce of alkali saturated with vinegar be dissolved in three ounces of spirit of wine, and a little more of any mineral acid than is sufficient to saturate the alkali be added, and the mass be then distilled, acetous ether will be obtained. Or if eight ounces of sugar of lead be gently dried, to deprive it of its water of crystallization, which amounts to rather more than one-fourth of its weight; if in this state it be
put

Methods of
preparing
acetous ether.

ETHER.
Acetous ether.

put into a glass retort, and a mixture of five ounces of vitriolic acid, and eight ounces of spirit of wine, be poured on it, and the whole exposed to distillation by a very gentle heat, the first ounce that passes over will consist of dulcified acetous acid, the next ounce will be almost all ether, and the whole quantity of ether produced will be near four ounces.

Acetous ether is not nearly so volatile as the nitrous or vitriolic; it burns with a blue flame, like spirit of wine.

Ligneous ether.

The empyreumatic acid of wood likewise affords an ether. For this purpose it may be distilled from beech, rectified a second time, and then saturated with alkali. Three pounds of the acid require about five ounces of alkaline salt. By evaporation to dryness, with subsequent solution, filtration, and evaporation, three ounces and a quarter of neutral salt are obtained. The concentrated acid of wood may be disengaged from this by distillation with two ounces of vitriolic acid; and the quantity of acid of wood thus obtained weighs an ounce and three quarters. By mixing this with an equal quantity of pure ardent spirit, and distilling it in a small retort, near two ounces and a quarter of ether are obtained.

Saccharine ether.

Equal parts of salt of sorrel and ardent spirit afford about one-fifth of their weight of ether. The acid of sugar likewise affords an ether with spirit of wine, which can hardly be supposed to differ from the foregoing, as the two salts are the same.

Phosphoric ether.

The acid of phosphorus does not produce an ethereal combination by direct distillation with ardent spirit: but it is said that the combination takes place with

with a due mixture of ardent spirit, vitriolic acid, and microcosmic salt; the phosphoric acid being expelled from its base, probably in a more dephlogisticated state than when obtained by suffering phosphorus to deliquesce in the air.

ETHER.

The acid of ants produces an ether, with spirit of wine, by similar treatment.

Ether produced by acid of ants:

Acid of benzoin does not produce ether by simple solution; and standing in spirit of wine; but, when one part of the acid of benzoin is distilled with three parts of ardent spirit, and one half part of common marine acid, the pure spirit comes first over, and afterwards an ethereal combination, one part of which floats upon water, and the other sinks to the bottom. This is not more volatile than acetous ether, and burns with a bright flame and smoke.

—by acid of benzoin.

The conversion of ardent spirit into ether, is a process concerning which much remains to be explained. It was formerly thought that the acid did nothing more than deprive the spirit of a quantity of water, which was before combined with it, and prevented its exhibiting oleaginous properties. It seems ascertained however, at present, that all the ethers contain a portion of that peculiar acid by whose action the spirit was changed; as may be shewn by suffering them to evaporate, or burning them away upon water. It appears therefore that the acid, or some of its component parts, combine either with the whole or part of the ardent spirit. Some chemists have with considerable probability asserted, that the basis, or acidifiable principle, of the acid combines with the spirit by the effect of a double affinity; so

General observations.

K k

that

ETHER.
 Theoretical
 observations.

that the vital air of the acid combines with a portion of acetous basis existing in the spirit, and forms vinegar; another portion combines with the vegetable principles existing in such a state as to form the saccharine acid; and, lastly, the acidifiable basis itself, which gave out this vital air, is supposed to combine with the undecomposed spirit, or vegetable inflammable matter, and rise in the form of ether. In this view of the subject, the nitrous ether is more particularly attended to, and the inferences are extended to other ethers; and oils are supposed to consist of vegetable inflammable matter, combined with the basis of an acid*.

* On Ethers, see Wiegleb's Chemistry, by Hopson, p. 510 et seq; Scheele's Essays, &c.

CHAP. X.

CONCERNING THE ACETOUS ACID.

AS most of the compounded vegetable acids are convertible; by nitrous acid and by other means, into acid of sugar; and this last into vinegar, it is evident that fermentation is only one of the processes which change the principles of plants into this least destructible of vegetable acids. All the vinegar however which is used in the common purposes of life, is obtained by fermentation. Crude vinegar contains not only that peculiar acid which is distinguished by the name of acetous, but likewise tartar, oily matter, and frequently some of the acids of the fruits from which it may have been procured. It is usual to purify it by distillation. The first product consists of a watery fluid, of a lively and agreeable smell, though scarcely acid. Next follows the acetous acid, commonly called distilled vinegar, which has a peculiar smell, less agreeable than that of the crude vinegar. As the distillation proceeds, the volatile product becomes more and more acid, somewhat darker coloured, and of an empyreumatic smell. The residue, after the greatest part of the fluid has been volatilized, has a deep brownish red colour, is considerably acid, and deposits a quantity of tartar. By distillation to dryness, it affords a reddish phlegm; more acid; an oil, at first light, and afterwards heavy; together with a small quantity of volatile alkali: the residual coal contains

ACETOUS
ACID.

Distilled vinegar, or acetous acid.

**ACETOUS
ACID.**

Concentration
of vinegar by
frost.

The most ad-
vantageous me-
thod of con-
centrating
vinegar.

tains much fixed alkali. The quantity of acid product reserved as distilled vinegar, is commonly about two-thirds of the whole.

Vinegar may be concentrated by frost, which separates its aqueous part. This process is particularly applicable to crude vinegar; as, by this means, the grateful flavour and peculiar properties are preserved. An ingenious method has been contrived for combining the two processes of distillation and congelation, in concentrating and purifying vinegar. In this way, good wine vinegar is to be distilled on a water bath. It is essential to reserve the phlegm, because the most fragrant parts come over first, and are retained in this fluid. The distilled vinegar and phlegm being then exposed to a freezing cold, and the ice taken out, a concentrated acid remains; which may be completely deprived of its extraneous and oily parts by repeated rectifications on a water bath. At the beginning of the rectification, a very spirituous fluid passes over; which being separated, and rectified by itself, yields a true and fine ether, of a very pleasant smell, and immiscible with water; which ether is to be added to the strong and purified vinegar obtained by the repeated rectifications. The author of this method observes, that the peculiar and unpleasant smell of distilled vinegar proceeds from some oily parts which pass over in the distillation; and that, when these parts have been separated by rectifying the acid concentrated by frost, it again recovers the pleasant smell of undistilled vinegar*.

* Lowitz, in Croll's Annals, quoted by Keir in his Chemical Dictionary, page 32.

Pure acetous acid enters into many combinations; and is recovered again by decomposition, though seldom perhaps in its original state. In many of its combinations it seems necessary that it should become more strongly acidified by attracting vital air from the atmosphere, or from other bodies. This circumstance has not been sufficiently attended to, to admit of a proper distinction of every case in which it may, or may not, happen. We shall not therefore attempt to point them out, except incidentally, and where the facts are clear.

ACETOUS
ACID.
Combinations
of acetous acid:

The acetous acid unites with earth of alum, or argillaceous earth, in considerable quantity, and forms a whitish saline mass, which is not crystallizable. There is however a disagreement among practical chemists respecting this combination. Some assert that it takes place very sparingly, and forms small needled crystals. These differences may probably depend on certain circumstances relative to the edulcoration of the earth of alum, after it has been precipitated from its solution by an alkali.

—with argilla-
ceous earth:

Calcareous earth is readily dissolved in the acetous acid, and forms a salt, the figure of whose crystals varies according to circumstances. It is permanent in the air, unless the acid be in excess; in which case it deliquesces. Its taste is sharp and bitter. When distilled without addition, the acid quits the earth, and appears in the form of an inflammable vapour, which condenses into a reddish brown liquor; and, when rectified, is very volatile and inflammable.

—with calca-
reous earth:

The acetous acid forms a saline mass by combina-

ACETOUS
ACID.

Combination of
acetous acid
with magnesia:

tion with ponderous earth, which does not crystallize, but, if dried, attracts moisture from the air.

Magnesian earth unites with acetous acid, and affords a very soluble salt; which, when perfectly saturated and evaporated, affords a viscid mass, resembling gum water. Its taste is sweetish at first, but afterwards bitter; and it is soluble in spirit of wine. Mere heat dissipates its acid, which may be obtained by distillation.

—with vegeta-
ble alkali.

Foliated earth
of tartar.

The combination of vegetable alkali with the acetous acid, produces the salt improperly called foliated earth of tartar. In the preparation of this salt, it is best to add an excess of acid. The evaporation must be carried to dryness on a water bath, in a glass or silver vessel. This salt cannot easily be crystallized. Its taste is penetrating, acrid, and urinous; heat decomposes it: by distillation, it affords an acid phlegm, empyreumatic oil, volatile alkali, and much elastic fluid, consisting of fixed and inflammable air. The residual coal contains much vegetable alkali. If foliated tartar be decomposed by the addition of vitriolic acid in distillation, the quantities being one part of the concentrated acid to two of the salt, in a tubulated retort, with a receiver, or apparatus of vessels adapted, the acetous acid immediately rises in the elastic form, with a strong effervescence, and is condensed in the receiver. This fluid is called radical vinegar, and its acid properties are more intense than those of common acetous acid. It is highly probable that this augmentation of acidity is produced by the transition of vital air from the vitriolic acid to the acetous; perhaps with the contrary transition of phlogiston.

Radical vine-
gar.

gifton. So that, while the acetous acid becomes more acidified, a portion of the vitriolic acid has its acidity diminished, and is converted into sulphureous acid, which comes over, and contaminates the product in the receiver.

ACETOUS
ACID.

Combinations
of acetous acid:

The acetous acid unites perfectly with the mineral alkali, and forms a crystallizable permanent salt. The properties of the acetous salt of mineral alkali do not remarkably differ from those of the foliated earth of tartar. By distillation with vitriolic acid, it affords a purer acetous acid than the foliated tartar does.

—with mineral
alkali:

The salt formed by uniting acetous acid with volatile alkali, has been called spirit of Mindererus, or acetous sal ammoniac. It does not easily crystallize; for which purpose it requires to be evaporated to the consistence of syrup, and then exposed to the cold. It soon attracts the moisture of the air, and has a sharp and burning taste. This salt is decomposable by heat; by lime and alkalis, which seize its acid; or by the mineral acids, which seize its base.

—with volatile
alkali:

The acetous acid has no effect on gold in the metallic state. When added to a solution of gold, it throws it down in the metalline form. The precipitate of gold effected by a fixed alkali becomes of a purple colour when digested with the common acetous acid. Radical vinegar dissolves it.

—with gold:

Silver is not acted on by acetous acid; though the calces of this metal, obtained by an alkali from nitrous acid, are soluble.

—with silver.

Platina is likewise insoluble in this acid; though its precipitate from aqua regia, by a fixed alkali, is soluble.

**ACETOUS
ACID.**

Acetous acid does not appear to be affected by mercury ; but it dissolves the mercurial calces. The crystals of this solution have a foliated appearance, resembling that of the acid of borax.

—with lead : Lead is dissolved with the greatest facility by vinegar. The manufacture of ceruse and sugar of lead has before engaged our attention.

—with copper: Copper is likewise soluble in vinegar, provided atmospheric air be present. The crystals of acetous acid and copper are improperly called distilled verdigrise. It is from this salt that radical vinegar has usually been distilled by mere heat, without addition. It is at first coloured by a portion of copper, which comes over ; for which reason it must be rectified by a gentle heat. The residue, after distilling the acetous salt of copper, consists of the metal in its reguline state ; whence it is seen that the vital air required to calcine the copper, comes over with the acid, which consequently is in a dephlogisticated or aerated state. The last portion of radical acid which comes over is inflammable, and congealable by cold.

—with iron. Iron is readily dissolved by the acetous acid, with a slight effervescence, and the disengagement of inflammable air. This solution deposits much calx of iron by evaporation ; and yields a few deliquescent crystals when cool. Very little action takes place between common vinegar and iron filings, unless by standing ; during which time, it is probable that the action of the air may contribute in some degree to the effect.

—with tin. When tin is digested with the acetous acid, a small portion appears to be taken up. The acid becomes turbid,

Compare page
318.

turbid, acquires a metallic taste, and affords a small quantity of precipitate by alkalis.

Bismuth and its calx are soluble in this acid, though sparingly. Nickel is dissolved, and the solution affords green crystals. Regulus of arsenic is insoluble, but its calx is taken up. The regulus of cobalt is likewise insoluble; its calx affords a pale rose-coloured solution, which is a sympathetic ink, and receives a green colour from marine acid. Zinc is soluble not only in its metallic and calciform states, but also, as it is said, when mixed with other metals: hence it should seem ill calculated to defend copper vessels from the action of this vegetable acid. The solution of zinc in common acetous acid affords plated crystals. Regulus of antimony is very sparingly acted on by the acetous acid; inasmuch that it might be judged that no action took place, if it did not impart an emetic quality to the fluid. Manganese is not acted on by this acid but with great difficulty, though repeated distillations at length combine the two substances. It has not been ascertained whether the acetous acid has any action upon wolfram or molybdena.

ACETOUS
ACID.

Metallic combinations.

Zinc an improper material to defend copper vessels.

B O O K II.

PARTICULAR CHEMISTRY.

SECTION VI.

CONCERNING THE PRODUCTS OF THE
ANIMAL KINGDOM.

C H A P. I.

A SHORT ENUMERATION OF SUCH ANIMAL SUB-
STANCES AS HAVE BEEN EXAMINED BY
CHEMISTS.

ANIMAL
SUBSTANCES.
analysis and
arrangement.

THE general structure and methods of analysing animal substances have been already noticed. It therefore remains only to enumerate and describe the several products of this kingdom which have engaged the attention of chemists. In the arrangement of these, as in the vegetable kingdom, we cannot, on account of the imperfect state of our knowledge, have recourse to the nature of their component parts; but shall

shall rather attend to the means by which they are respectively afforded or obtained. In this way we may ANIMAL
SUBSTANCES.
consider the parts of animals as either,

1. Such as are usually obtained without destroying Enumeration.
life. These are milk, eggs, urine, excrement, the matter of perspiration, ambergris, &c.; wax, honey, gum lac, silk, hair, horn, feathers, &c. Or,

2. Such parts of animals as are obtained by destroying them, or depriving them of life. These are blood; various solids, confounded under the name of flesh, fat, spermaceti; bile, the gastric juice, and several acids; together with calcareous earth, and other substances, common to the mineral and vegetable kingdoms.

CHAP. II.

CONCERNING MILK, EGGS, HONEY, WAX, LACCA, SILK,
HAIR, HORN, ETC.

MILK.

General characters of milk.

MILK is a well known fluid, secreted in peculiar vessels of the females of the human species, of quadrupeds, and of cetaceous animals, and destined for the purpose of nourishing their young. Its appearance and component parts are not altogether the same in various species of animals; but the differences have not yet been well ascertained. For this reason, in treating of milk, our attention will be confined to that of the cow, because the most abundantly met with. This fluid is of a beautiful opaque white colour, nearly as limpid as water, and of a pleasant emulsive taste. Its appearance on the stage of a microscope exhibits an infinity of minute opaque globules floating in a transparent fluid.

Effects of heat on cows milk.

Cows milk, distilled on a water bath, affords a tasteless phlegm of a faint smell, which is capable of putrefying. A stronger heat coagulates it. It is sometimes gradually dried into a substance which is a kind of saccharine extract, and may again be diffused in water. By destructive distillation, milk affords an acid, a fluid oil, a concrete oil, and volatile alkali. Its residual coal contains a small quantity of vegetable alkali, some salt of Sylvius, and phosphoric calcareous salt.

When

When milk is left to spontaneous decomposition, at a due temperature, it is found to be capable of passing through the vinous, acetous, and putrefactive fermentations. It appears however, probably on account of the small quantity of ardent spirit it contains, that the vinous fermentation lasts a very short time, and can scarcely be made to take place in every part of the fluid at once by the addition of any ferment. This seems to be the reason why the Tartars, who make a fermented wine from mares milk, called koumish, succeed by using large quantities at a time, and agitating it very frequently.

MILK.

Fermentation
of milk.

Page 482.

When milk is left exposed for some hours in a state of repose, a small quantity of thick fluid rises to the top, and is known by the name of cream. This contains the fat substance called butter, which is afterwards separated from it by agitation in the act of churning. The remainder afterwards becomes sour, and undergoes a coagulation which separates it into two parts—a solid curd; and a fluid, called serum or whey. This sour whey contains a peculiar acid, called the acid of milk, and likewise a portion of vinegar. The peculiar acid does not rise in distillation, but may be separated by evaporating the filtered whey to one eighth; and precipitating the phosphoric salt by the addition of lime-water, which fully saturates its acid: the fluid is then to be diluted with three times its weight of water; and the redundant lime precipitated by saccharine acid, in which operation the excess of the last-mentioned acid may be guarded against by the test of a small portion of lime-water. This purified liquor must then be evaporated to the con-

Cream.

Butter.

Acid of milk.

sistence

MILK.istence of honey; and the other foreign substances it may contain will be separated by the addition of pure ardent spirit, which takes up the acid of milk only. The decanted solution being then diluted with water, and heated, the ardent spirit flies off, and leaves the acid of milk behind, dissolved in the water.

Acid of milk.

Combinations with various substances.

This acid does not afford crystals; and, when evaporated to dryness, it deliquesces again by exposure to air. With vegetable alkali it affords a deliquescent salt, soluble in ardent spirit. With mineral alkali it affords a salt possessing the same properties. With volatile alkali it produces a deliquescent salt, which yields much of its alkali by distillation before the acid is destroyed by heat. With lime, clay, and ponderous earth, it forms deliquescent salts; but with magnesia it affords small crystals, which at length deliquesce. The acid of milk dissolves iron and zinc, and produces inflammable air. Copper affords a dark blue solution, which does not crystallize. Lead is dissolved after some days digestion, and affords vestiges of vitriolic acid. Bismuth, cobalt, antimony, tin, mercury, silver, and gold, are not affected by this acid in a digestive or boiling heat. Destructive distillation decomposes the acid of milk: water first comes over; then a weak acid, resembling the empyreumatic acid of tartar; afterwards some empyreumatic oil, with more of the same acid, and also fixed air, and the heavy inflammable air. A coal remains in the retort.

Curd.

If any vegetable or mineral acid be added to milk, the curd is separated, and coagulates into one mass, if the

the mixture be assisted by the application of heat. The curd obtained by means of mineral acid, always manifests signs of acidity, and is partially soluble in boiling water. If any neutral, earthy, or metallic salt be added to saturation in milk, it likewise separates the curd. Sugar and gum-arabic produce a similar effect. Caustic alkalis dissolve the curd, by the assistance of a boiling heat; and it may again be coagulated by the addition of acids.

MILK.

Curd.

The coagulation of milk, in the manufacture of cheese, is effected by the addition of rennet, which is the infusion of the stomach of a sucking calf in water, prepared in various ways, according to the fancy of the makers. This fluid seems to owe its properties to the gastric juice of the animal. The separated curd is wrapped in a cloth with salt, and pressed, to deprive it of the superfluous whey; after which, it is preserved for several months or years before it is considered as fit for use.

Manufacture of
cheese:

Cheese, when decomposed by destructive distillation, —properties. affords an alkaline phlegm, an heavy oil, and much volatile alkali. Its residual coal is difficult to incinerate, and does not afford fixed alkali. By treating it with the nitrous acid, it is found to contain lime and phosphoric acid. Cheese is not soluble in water. Hot water hardens it.

The saccharine substance upon which the ferment- Sugar of milk. ing property of milk depends, is held in solution by the whey which remains after the separation of the curd in making cheese. This is separated by evaporation in the large way, for pharmaceutical purposes, in various parts of Switzerland. When the whey has been

MILK.
Sugar of milk.

been evaporated by heat to the consistence of honey; it is poured into proper moulds, and exposed to dry in the sun. If this crude sugar of milk be dissolved in water, clarified with whites of eggs, and evaporated to the consistence of syrup, white crystals, in the form of rhomboidal parallelopipedons, are obtained.

—Decomposition by heat:

—treatment with nitrous acid.

Sugar of milk has a faint saccharine taste, and is soluble in three or four parts of water. It yields by distillation the very same products that other sugars do. It is remarkable, however, that the empyreumatic oil has a smell resembling flowers of benzoin. Twelve ounces of diluted nitrous acid being poured upon four ounces of finely powdered sugar of milk, in a glass retort, on a sand-bath, with a receiver annexed, the mixture became gradually hot, and at length effervesced violently, and continued to do so for a considerable time after the retort was taken from the fire. It is necessary, therefore, in making the experiment, to use a large retort, and not to lute the receiver too tight to the retort. After the effervescence had in some measure subsided, the retort was again placed on the sand-bath, and the nitrous acid distilled off, till the mass acquired a yellowish colour. This yellow fluid exhibited no crystals. Eight ounces more of the same nitrous acid were therefore added, and the distillation again repeated, till the yellow colour of the fluid disappeared. The fluid became inspissated by cooling; it was therefore redissolved in eight ounces of water, and filtered. Seven drams and a half of a white powder remained on the filter, and the clear solution afforded crystals of saccharine acid. The mother water was again treated several times with nitrous acid, by which

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which means the whole was at length changed into saccharine acid.

MILK.

The white powder that remained on the filter was found to be combustible like oil, in a red-hot crucible, without leaving any mark of ashes behind. It was soluble in sixty times its weight of boiling water; and one fourth part separated by cooling, in the form of very small crystals. The remaining mass being then collected, by evaporating the greatest part of the water, left behind a small portion of the acid of sugar, of which it had not been so exactly deprived by edulcoration on the filter. From these circumstances it appeared that the white matter was a salt; and, upon examination, it was found to be an acid, possessing the following properties:

Peculiar acid of sugar of milk.

With all the soluble earths it forms salts insoluble in water. It disengages fixed air from the mild alkalis. With vegetable alkali it forms a crystallizable salt, soluble in eight times its quantity of boiling water, and separable for the most part by cooling. With the mineral alkali it forms a salt which requires only five parts of boiling water for its solution. Both these salts are perfectly neutral. When saturated with volatile alkali, it forms a salt which, after being gently dried, has a sourish taste. It does not perceptibly act on the metals; but forms with their calces, in solution, salts of very difficult solubility, which are therefore precipitated*.

Combinations.

The principles of milk appear to be united together partly in a chemical, and partly in a mechanical

* On milk and its acid, and on the acid of the sugar of milk, consult the Chemical Essays of Scheele.

MILK.

Separation of
butter from
cream :

manner ; and the butter seems to rise to the top in consequence of the greater specific gravity of the whey through which it is dispersed. Cream consists of butter mixed with much whey and curd. It is generally thought that the separation of the butter by churning is effected simply by the agitation, which causes the fatty particles to strike against each other, and coagulate into larger masses. There seems however some reason to think that a chemical effect takes place in this operation ; in which the intimate mixture of atmospheric air with the fluid may perhaps have some effect.

—its proper-
ties.

Butter appears to be of the nature of fat oils ; but is considered by most nations as infinitely preferable to them, as an article of food. By distillation on a water bath it gives out the aqueous fluid which, from the manner of its fabrication, is distributed through its mass. Its products by destructive distillation nearly resemble those of other oils. They consist of an acid of a strong and penetrating smell, a fluid oil, and a concrete oil of the same smell as the acid. These oils, like others obtained in similar circumstances, may, by repeated rectifications, be converted into volatile oils, of the nature of those which are called essential. In other respects, butter possesses the same properties and may be applied to the same uses as fat oils. It becomes rancid by spontaneous decomposition, which develops its acid ; and with fixed alkalis it forms soap.

EGGS.

The eggs of birds considerably resemble milk in their component parts, though their peculiar structure and

and organization constitute a great and essential difference, applicable to the purposes of generation, into which our present views do not require us to proceed. The white of egg does not greatly differ from the curd of milk or cheese. When it is mixed with water, it forms a coagulum or curd by the addition of acids. Heat coagulates the white of egg, without depriving it of weight; which is a very singular fact, and has not yet been well explained. The white of egg however appears to differ, in some respects, from curd. It is said to afford a small portion of sulphur by sublimation; and it contains the mineral alkali in a disengaged state.

MILK.

Resemblance
between white
of egg and curd
of milk.

The yolk of egg appears to be an animal emulsion, which is diffusible in water. It contains an oil, which may be separated by drying, and afterwards subjecting it to pressure.

Yolk of egg.

Honey and wax may be considered as animal substances, because afforded by the bee; though it is not improbable but these laborious insects may extract them from the vessels of plants, and deposit them in their hives without alteration.

Honey and
wax.

Honey which is purified by solution and crystallization, perfectly resembles the saccharine juices of vegetables which have undergone the like treatment. It affords the same product as sugar by destructive distillation. Nitrous acid converts it into the saccharine acid, and its aqueous solution is susceptible of all the stages of fermentation. It is accordingly, as we have before observed, made use of in the preparation of a vinous liquor.

Purification of
honey.

Page 432.

WAX.

Distillation of
wax.

Butter of wax.

Bleaching.

Difference be-
tween wax and
tallow.

Wax is a concrete substance, which greatly resembles the more solid fixed oils, and unites with oily substances in all proportions. Its products, by destructive distillation, are the same as those of other fat substances. The concrescible oil obtained by distillation of this substance, is called butter of wax. Bees-wax is of a yellow colour, but becomes white by exposure to air: this effect takes place only at or near the surface or place of contact: for which reason the bleachers of wax find it necessary to renew the surface frequently. This is done either by causing the melted wax to pass through a number of holes in the bottom of a vessel into another vessel of water, by which means it undergoes that kind of division which, in metallic bodies, is called granulation; or it is gently poured upon a wooden cylinder, which is turned round in a vessel filled with water to such a height, that half of the cylinder is immersed. In this way, the wax forms a number of thin flakes, that do not adhere to each other, but may be taken off, and exposed to the action of the air. The dephlogisticated or aerated marine acid bleaches wax very speedily; from which fact it appears that the wax owes its whiteness, and the greater consistency it acquires, to an absorption of the vital part of the atmosphere. Wax seems to differ from tallow, or concrete oil, principally in this circumstance: and this last substance becomes likewise harder and whiter by long exposure to the air, in thin masses: as, for example, when it is spread out upon the surface of water. Wax being already combined with a portion of vital air, does not burn with so luminous a flame as tallow or oil. But it possesses a very great

great advantage in the fabrication of candles, which arises from the circumstance of its freezing point being placed at a considerably higher temperature than those of either of the other two substances.

WAX.

To explain this advantage, it must be considered, that oils do not take fire, unless they be previously volatilized by heat. The wick of a candle, or lamp, answers this purpose. The oil rises between the fibres of the wick by the capillary attraction. Heat is applied to the extremity of the wick, which volatilizes and sets fire to a portion of the oil. While this is dissipated by combustion, another portion passes along the fibres, and supplies its place by becoming heated and burned likewise. In this way a constant combustion is maintained. It must be remarked, however, that a candle differs from a lamp in one very essential circumstance, namely, that the oil, or tallow, is liquefied only as it comes to be in the vicinity of the conflagration; and this fluid is retained in the hollow of the part which is still concrete, and forms a kind of cup. For this reason, it is found necessary that the wick should not be too thin; because, in this case, it would not carry off the fluid as fast as it becomes fused; and the consequence would be, that it would run down the sides of the candle: and, as the inconvenience arises from the fusibility of the oil, it is plain that a more fusible candle will require a larger wick; or that the wick of a wax candle may be made thinner than that of one of tallow.

The difference of effect, in illumination, between a thick and a thin wick, cannot be better shewn than by remarking the appearances produced by both. When

WAX.

The use and
effects of the
wick in can-
dles.

a candle with a thick wick is first lighted, and the wick snuffed short, the flame is perfect and luminous, unless its diameter be very great; in which last case, there is an opaque part in the middle, where the combustion is impeded for want of air. As the wick becomes longer, the space between its upper extremity and the apex of the flame is diminished; and consequently the oil which issues from that extremity, having a less space of ignition to pass through, is less completely burned, and passes off partly in smoke. This evil continues to increase, until at length the upper extremity of the wick projects beyond the flame, and forms a support for an accumulation of soot, which is afforded by the imperfect combustion. A candle, in this situation, affords scarcely one tenth of the light which the due combustion of its materials would produce; and tallow-candles, on this account, require continual snuffing.—But, on the contrary, if we consider the wax candle, we find that, as its wick lengthens, the light indeed becomes less. The wick however, being thin and flexible, does not long occupy its place in the centre of the flame; neither does it, when there, enlarge the diameter of the flame so as to prevent the access of air to its internal part. When its length is too great for the vertical position, it bends on one side; and its extremity, coming in contact with the air, is burned to ashes; excepting such a portion as is defended by the continual afflux of melted wax, which is volatilized, and completely burned, by the surrounding flame. We see therefore that the difficult fusibility of wax renders it practicable to burn a large quantity of fluid by means of a small wick; and that

this small wick, by turning on one side in consequence of its flexibility, performs the operation of snuffing upon itself, in a much more accurate manner than it can ever be performed mechanically.

WAX.
LACCA.

Wax is not soluble in ardent spirit.

Lac, or lacca, is a substance well known in Europe, under the different appellations of stick-lac, shell-lac, and seed-lac. The first is the lac itself, which is a brown semi-transparent substance, in pretty considerable lumps, with woody parts adhering to it. Seed-lac is the stick-lac broken in pieces, and appearing in a granulated form. Shell-lac is the substance which has undergone a simple purification.

Stick-lac, shell-lac, and seed-lac :

Lac is the product of an insect*, which deposits its eggs on the branches of a tree called Bihar, in Assam, a country bordering on Thibet, and elsewhere in India. It appears designed to answer the purpose of defending the eggs from injury, and affording food for the maggot in a more advanced state. It is formed into cells, finished with as much art and regularity as an honey-comb, but differently arranged; and the inhabitants collect it twice a year, in the months of February and August. For the purification, it is broken into small pieces, and put into a canvas bag of about four feet long, and not above six inches in circumference. Two of these bags are in constant use, and each of them held by two men. The bag is placed over a fire, and frequently turned, till the lac is liquid enough to pass

—its production.

* For a description, consult Kerr, in the Phil. Trans. vol. lxxi. p. 374.

LACCA.
Purification of
lac.

through its pores ; when it is taken off the fire, and twisted in different directions by the men who hold it, at the same time dragging it along the convex part of a plantain tree prepared for that purpose ; and, while this is doing, the other bag is heating, to be treated in the same way. The mucilaginous and smooth surface of the plantain tree prevents its adhering ; and the degree of pressure regulates the thickness of the coating of lac, at the same time that the fineness of the bag determines its clearness and transparency*.

Characters.

Lac is not entitled to arrangement either with oils, resins, or gums. It is not soluble either in water, or in fat oils. Some essential oils appear to extract a dilute tincture. The action of the acids upon lac, either when concentrated or diluted, does not seem to be considerable ; but this requires more particular examination, especially as far as relates to the nitrous acid. Ardent spirit acts but feebly on this substance.

By standing upon it in the cold, it forms a clear tincture, apparently by dissolving only a part of its principles ; but, when digested in a moderate heat, the whole of the lac unites with the spirit, and forms a turbid mixture, or imperfect solution, of a gummy appearance, which does not afterwards become clear.

Hard varnish.

In this way, however, with judicious management, it appears practicable to form a very hard opaque varnish, resembling that of China or Japan. The principal use of lac is in the manufacturing of sealing-wax, and in dyeing scarlet. For this last purpose, half a dram of powdered comfrey root is to be boiled in a quart of

* Saunders, in Phil. Transf. vol. lxxix.

water

water for a quarter of an hour, and some powdered gum lac digested in the decoction for two hours. The tincture appears of a fine crimson colour; and the remaining lac, if the quantity of liquor has been sufficient, is of a pale straw colour. The clear tincture being then poured off, and a solution of alum gradually added, the colouring matter subsides, in the form of one of the powders called lakes, which amounts to about one fifth part of the weight of the lac. This fecula is dissolved in warm water, with the addition of a proper quantity of the solution of tin in aqua regia: and the liquor, which is of a fiery red colour, is then to be poured into boiling water, impregnated with salt of tartar, or the mild fixed vegetable alkali. The bath, thus formed, is a good scarlet dye for woollens, though less lively than that of cochineal.

LACCA.

SILK.

Uses of lac.

Lewis on Neumann.

Silk is a well-known substance, which serves as a nidus for the chrysalis of the silk-worm. Its extensive utility, when contrasted with the small prospect of advantage which its appearance in the crude state seems to afford, may serve to stimulate our industry in the examination of other natural products; many of which, though neglected at present, might, on enquiry, be found equally beneficial to society. This substance seems to hold a middle rank between animal and vegetable matters. It affords volatile alkali by distillation, and gives out phlogisticated air when treated with nitrous acid. By distilling the nitrous acid from this substance, the acid of sugar is obtained, and likewise a peculiar oil. The phalæna, or moth of the silk-worm, ejects a liquor which appears to contain

Silk, and the acid of silk-worms.

SILK. WOOL. contain a peculiar acid, hitherto little examined. It is obtained in a state of purity by infusing the chrysalides in ardent spirits, and subsequent evaporation.

Animal excrecences.

The hair and wool of animals do not seem to differ greatly from silk. They afford much acid of sugar, when treated with nitrous acid. It is probable that horns, feathers, and other similar excrecences of animals, are nearly of the same nature.

CHAP. III.

CONCERNING THE EXCREMENTITIOUS PARTS OF
ANIMALS.

THE substances which are rejected out of the bodies of animals, as useless, are urine, and the fecal matter, or excrement. These differ in the various species of animals, according to their respective natures and food. But little attention has been paid by chemists to the urine or excrements of any animals except the human species. We have already had occasion to mention the contents of urine, in treating of the phosphoric acid; in our account of the mineral kingdom; and shall therefore, in the present place, confine our remarks to that peculiar deposition which is known by the name of the urinary calculus, or stone of the bladder.

EXCREMEN-
TITIOUS
MATTERS.

Urine and fecal
matter.

The matter which forms these hard concretions is found in all urine; and is deposited by cooling, after the greatest part is evaporated. Heat again dissolves it. In about three hundred times its weight of boiling water it is either totally soluble, or it leaves a very inconsiderable residue, which seems to be an impurity. As the fluid becomes cold, most of the calculus is again separated in fine crystals. The vitriolic acid dissolves it with effervescence; the marine acid does not appear to act upon it; and the nitrous acid totally dissolves it. This solution affords no precipitate by the acid of sugar, though the vitriolic acid throws down a small portion of selenite: whence it appears that the calculus

Stone of the
bladder.

EXCREMEN-
TITIOUS
MATTERS.

Acid of the
stone of the
bladder.

calculus contains some lime. Pure alkalis dissolve it, as does likewise lime-water. By destructive distillation, the calculus affords fluid volatile alkali, and a sublimate of a brown colour, which by a second sublimation becomes white. This has a fourish taste, is easily soluble in boiling water, and also in ardent spirit.

From the above, and other experiments, it appears that the calculus consists of an acid of a volatile nature, together with some gelatinous or oily matter, and a small portion of lime. The acid itself may probably be a compound salt with excess of acid, similar to the combinations of mineral alkali and phosphoric acid, vegetable alkali and tartareous acid, and some others which were considered as simple acids, until chemists had devised means of separating their component parts. We see therefore that the analysis of the stone of the bladder has not yet been perfectly made.

Hornberg's experiments on human excrement.

However important the knowledge of the component parts of fecal matter may be, to facilitate our acquaintance with the animal system, it may easily be imagined that the pursuits of the majority of chemists would be directed to departments of the science which promised effects of a less disgusting nature. We possess but one set of experiments made on this substance, by Hornberg, at the beginning of the present century. This philosopher, in consequence of alchemistical information, instituted a set of operations upon the fecal matter of men fed entirely upon bread of Gonesse*, and Champagne wine. He found that,

* A small town near Paris, where the most excellent bread is made.

when

when recent, it afforded, by distillation to dryness, an aqueous, clear, insipid liquor of a disagreeable odour, which contained no volatile alkali; but, by continuing to distil the residue by a graduated fire, he obtained fluid and concrete volatile alkali, a fetid oil, and a coaly residue; substances which this imperfect method of analysis exhibits with every kind of animal substance.

EXCREMEN-
TITIOUS
MATTERS.

Homburg's ex-
periments on
the human fe-
cal matter.

The human fecal matter, by lixiviation in water, filtration, and subsequent evaporation, afforded an oily salt resembling nitre, which was fused on ignited coals, and took fire when heated to a certain degree in closed vessels. The same fecal matter, after it had undergone a complete putrefaction for forty days, in the gentle heat of a water-bath, afterwards afforded by distillation a colourless oil without smell, which was the thing sought after; but it did not fix mercury, as he had been led to expect.

Imperfect as this examination is, it is rendered still less generally applicable by the peculiar nature of the aliments from which the matter originated. For it cannot be doubted but that, as the excrements are the residue of the food taken, they will differ according to the nature of that food; as is indeed sufficiently evinced from their more obvious qualities.

It is at present a general opinion*, that ambergris is an excrementitious substance, voided by the phy-

Ambergris.

* Chiefly grounded on the enquiries and observations of Dr. Svedenborg, in the Phil. Trans. for 1783. Mr. Magellan however mentions an undoubtedly vegetable ambergris, gathered from the tree by M. Aublet, and examined by Rouelle. Cronstedt's Mineralogy, p. 458.

EXCREMEN-
TITIOUS
MATTERS.

Characters of
ambergris.

feter macrocephalus, or spermaceti whale. Ambergris is found in the sea, near the coasts of various tropical countries; and is either white, black, ash-coloured, yellow, or grey, with black or yellow specks. A slight warmth softens it, like pitch; by a greater heat it takes fire; and its chemical products resemble those of bitumens, among which it has usually been ranked. Oils dissolve it; as does likewise ardent spirit, if its quantity be twelve times that of the ambergris, and its temperature boiling. An addition of essential oil promotes the solution.

Matter of perspiration, &c.

Various other matters are rejected from animals; such as the matter of perspiration, the nasal mucus, tears, &c. But as none of these have been examined, we shall avoid entering into any detail of their obvious properties.

CHAP. IV.

CONCERNING THE BLOOD, AND THE OTHER FLUID
OR SOLID MATTERS, OF WHICH ANIMALS
ARE FORMED.

THE fluid which first presents itself to observation when the parts of living animals are divided or destroyed, is the blood, which circulates with considerable velocity through vessels called veins and arteries, distributed into every part of the system. It can scarcely admit of doubt but that the component parts, or immediate principles of the blood, must differ in the various and exceedingly dissimilar genera and species of animals which occupy the land and waters of the globe; and that there are likewise differences in the state or composition of this fluid in the same animal, according to its state of health, as well as the situation of the vessels from which it may be extracted. These differences can be ascertained only by the united efforts of the anatomist and the chemist. But as the difficulty and extent of the subject have hitherto prevented any considerable progress, it becomes an object of necessity to confine our attention to the blood of man, or of such quadrupeds as afford this fluid in a state not obviously different from that of the human species.

PARTS OF
ANIMALS.

The blood :

—differences.

Recent blood is uniformly fluid, and of a saline or slightly ferruginous taste. Under the microscope it appears

PARTS OF
ANIMALS.
Characters of
the blood.

appears to be composed of a prodigious number of red globules swimming in a transparent fluid. After standing for a short time, its parts separate into a thick red matter, or crassamentum, and a fluid called serum. If it be agitated till cold, it continues fluid; but a consistent polypous matter adheres to the stirrer, which by repeated ablutions with water becomes white, and has a fibrous appearance: the crassamentum becomes white and fibrous by the same treatment. If blood be received from the vein in warm water, a similar filamentous matter subsides, while the other parts are dissolved. Alkalis prevent the blood from coagulating; acids, on the contrary, accelerate that effect.

Habitudes with
acids, &c.

In the latter case the fluid is found to contain neutral salts, consisting of the acid itself united with mineral alkali, which consequently must exist in the blood, probably in a disengaged state. Ardent spirit coagulates blood. On the water-bath, blood affords an aqueous fluid, neither acid nor alkaline; but of a faint smell, and easily becoming putrid. A stronger heat gradually dries it, and at the same time reduces it to a mass of about one eighth of its original weight. In this state it slightly attracts the humidity of the air, and effervesces with acids; but by a longer exposure, for some months, it becomes covered with an efflorescence of mild mineral alkali. By destructive distillation this animal fluid affords a watery liquor, holding in solution a neutral salt, with excess of volatile alkali, but whose acid part has not been well ascertained: next follows a light oil, a dense coloured oil, and foul or oleaginous volatile alkali. The residue is a coal of very difficult incineration, containing common salt,

Distillation.

mineral

mineral alkali, and an earth, which is probably a combination of lime and phosphoric acid.

PARTS OF
ANIMALS.

The serum of blood exhibits marks of a disengaged alkaline salt, and is greatly disposed to putrefy. It unites with water in all proportions, and forms a milky fluid, which may be coagulated by acids or ardent spirit. An increase of temperature causes serum to become consistent, with little or no loss of weight, in the same manner as the white of egg; and it is accordingly used for the same purpose in clarifying liquids. From a variety of experiments, it appears highly probable that white of egg, serum of blood, and the pure curd of milk, do not essentially differ from each other: and to these we may perhaps add the vegetable gluten, which considerably resembles cheese.

Serum of blood:

—resembles
white of egg,
curd, and vegetable
gluten:

Alkalis render the serum of blood more fluid; acids coagulate it, and exhibit the neutral salt they would have produced by direct combination with mineral alkali. The coagulum affords, by distillation, phlegm, mild volatile alkali, and a thick fetid oil; and the residue affords mild mineral alkali. These products are the same as are afforded by the serum itself.

—with alkalis
and acids:

Serum is also coagulated by ardent spirit, merely by the loss of part of its water. When rendered concrete by heat, and exposed to the action of nitrous acid, it affords phlogisticated air by a slight heat, which is followed by nitrous air; and the residue affords acid of sugar, together with a small portion of acid of apples.

—with ardent
spirit:

—nitrous acid.

The crassamentum of blood, when treated in the way of distillation, becomes dry and brittle, at the same time that it emits an alkaline phlegm; this is followed by an empyreumatic stinking oil, and concrete volatile alkali.

M m

alkali.

**PARTS OF
ANIMALS.**

alkali. A spongy brilliant coal remains, which by treatment with vitriolic acid is found to contain mineral alkali and iron, as appears by the production of Glauber's salt and martial vitriol: coaly matter and phosphorated lime are then left behind.

Fibrous part of
blood:

--with acids.

Destructive
distillation.

The fibrous matter, which is obtained by washing the red part of the blood, resembles the serum in many of its properties; though it differs from it in not being soluble in water, in becoming hard by a very gentle heat, and in not combining with alkalis. Acids unite with it, and in particular the nitrous acid dissolves it, and extricates phlogisticated and nitrous air; while the residue, by evaporation, affords acid of sugar in crystals, a peculiar oil in flocks, and the phosphoric salt of lime. Its volatile products by destructive distillation are nearly the same as those of serum: but its residue contains no salt, except the combination of lime and phosphoric acid; the other salts it might have contained having probably been carried off during the washing. Marine acid forms a green jelly with the fibrous parts of the blood.

Soft parts of
animals.

Jelly or glue.

The soft and flexible parts of animals appear to be composed of principles greatly resembling those of the blood. When they are boiled in water, the fluid extracts that peculiar animal substance which is known by the name of jelly or glue. This is afforded by the white parts most plentifully, though it is found in almost every part of the animal solids. Its appearance and insipidity, together with its other obvious properties, are well known. It is soluble in water, in all proportions; is more fluid when hot than when cold.

cold. Alkalis and acids both dissolve it. By spontaneous decomposition it first becomes acid, and soon afterwards putrefies. By destructive distillation it affords an alkaline phlegm, an empyreumatic oil, and a small quantity of volatile alkali. The residual coal is voluminous, not easily incinerated, and contains common salt, with the phosphoric salt of lime. The habitude of the nitrous acid with glue, or jelly, is the same as with other animal substances; phlogisticated air and nitrous air are disengaged, and the residue affords acid of fugar.

PARTS OF
ANIMALS.

Jelly or glue.

Besides the parenchymatous and cellular substance of which the muscles of animals are formed, their vessels contain fluids possessed of various properties. These may be obtained by pressure, and the judicious application of water and ardent spirit, either with or without heat. If flesh be washed in cold water, a portion of blood and gelatinous matter, together with saline matter, are extracted: the residue being digested in ardent spirit, is by that means deprived of an extractive or saponaceous substance; and subsequent ebullition in water dissolves the gelatinous part, at the same time that it deprives it of such portions of extract and salt as had been defended from the action of the two former solvents. The fat is also liquefied by this operation, and arises to the surface. By slow evaporation of the aqueous solution, made in the cold, the albuminous part, or serum, coagulates, and may be separated on the filter: the filtered liquor will afford its salt by evaporation: the spirituous solution deposits the extractive matter by evaporation: and the decoction affords the jelly, with the fat oil, which swims

Analysis of the
flesh of ani-
mals.

PARTS OF
ANIMALS.Analysis of the
flesh of ani-
mals.

at the surface and congeals by cooling. The remaining solid substance consists merely of the fibrous matter, which is white, insipid, and insoluble in water. This affords much volatile alkali, and a very fetid oil, by distillation; and it gives out a large quantity of phlogisticated air when treated with nitrous acid. In a word, it has all the characters of the fibrous part of the blood, and is probably formed by the deposition of that substance*.

The extractive or saponaceous matter obtained by the evaporation of the spirit, is soluble likewise in water; it swells up and liquefies by heat, and emits a smell somewhat resembling that of burned sugar: it is this substance which predominates in the brown crust that covers the surface of roasted meat. The salt afforded by the decoction of flesh has not been perfectly examined; but it seems to consist of the phosphoric acid, united partly with the vegetable alkali, and partly with lime.

Fat of animals.

The fat of animals is a substance of the same nature as those oils which are called fat oils in the vegetable kingdom. Its consistence is various in different animals, and in different parts of the same animal. The fat of the human species and of quadrupeds is consistent, and of a white or yellowish colour; the fat of the internal parts being usually firmer than that which is placed among the muscles. It possesses all the characters of vegetable fat oils; though the crude fat of animals appears to contain a considerable quantity of

* Fourcroy, iv. 417.

mucilage or jelly peculiar to that kingdom, which may for the most part be washed off by agitation in a large quantity of hot water. PARTS OF
ANIMALS.

The acid of fat is considered as belonging to the animal kingdom, though indeed it is no less abundant in the fat oils of vegetables. It may be obtained by distillation. Or otherwise a quantity of suet may be melted, and mixed with quick-lime: as soon as the mixture is cold, it must be boiled in a large quantity of water. After filtration and evaporation, the calcareous salt formed by the combination of that earth with the acid of the fat, is obtained of a brown colour. A slight calcination in a crucible renders it purer, by the destruction of a portion of inflammable matter; and by solution, filtration, and the addition of a certain quantity of fixed air to precipitate the superfluous lime, a clear solution of the acid of fat, neutralized with calcareous earth, is obtained. Evaporation of this fluid affords the pure white salt; and this, when distilled with the addition of vitriolic acid, affords the acid of fat, which comes over into the receiver, while the lime and vitriolic acid remain in the retort, in the form of selenite. Acid of fat.

The general characters of the acid of fat are the following:—It is liquid, fuming, and of a penetrating smell; decomposable by fire, which turns it yellow, and extricates or produces fixed air. Blue colours are strongly reddened by it. Water dissolves it in all proportions. With lime, and also with the fixed alkalis, it forms crystallizable salts, which are not decomposed by heat. Siliceous earth appears to be Characters of
the acid of fat.

PARTS OF soluble in, or corroded by, this acid ; and it acts on
ANIMALS. several of the metals.

Method of obtaining spermaceti.

Spermaceti is a peculiar substance, of the nature of fat oil, which is found in the head of a species of whale. One of these fishes affords some tons of brains, which are first grossly freed from the oil, by draining and pressing ; and afterwards more perfectly purified, by steeping them in a ley of alkaline salt and quicklime, which converts the remains of the oily matter into soap. The brains being then washed with water, appear of a silver whiteness ; and nothing more is then required to complete the preparation, than to cut them in pieces with wooden knives, and spread them abroad to dry. Good spermaceti is in fine white flakes, glossy, and semi-transparent ; rather unctuous to the touch, though dry, and in some measure friable. Its smell is faintish, though not disagreeable ; and it has scarcely any taste, on account of its being either nearly or totally insoluble in the saliva : exposure to the air renders it yellowish and rancid in process of time ; and that the more readily in proportion as the original purification has been less complete. It may however be rendered white and sweet again, by steeping it afresh in caustic alkali, and washing it in water.

—and habitudes.

It is scarcely, if at all, more combustible than tallow ; and is a much better material for candles, because less fusible and greasy. By distillation it totally rises, leaving no coal behind ; but its component parts do not rise together. Four ounces of this substance afforded three ounces and a half of a clear,

clear, yellowish, butyraceous oil, resembling oil of wax in smell, and coagulate in the cold, like that substance; a drachm and a half of the product consisted of phlegm, and the rest was wasted or dissipated in the process *.

PARTS OF
ANIMALS.

Water has no other effect upon spermaceti, when boiled with it, than to separate a small quantity of mucilaginous, or perhaps saponaceous matter, which is probably an impurity. Oils dissolve it, by the assistance of heat; hot ardent spirit likewise dissolves it, but lets the greatest part fall upon cooling; ether dissolves it very readily; sulphur combines with this substance in the same manner as it does with fat oils; the nitrous and marine acids have no action on it; concentrated vitriolic acid dissolves it, but lets it fall again by heat.

Habitudes of
spermaceti
with various
substances.

It has been conjectured that this singular substance bears the same relation to fat oils as camphor does to the essential oils. Wax appears to have the same relation to fixed oils, as resin has to the essential; that is to say, both have been rendered concrete by the absorption of vital air. But spermaceti and camphor seem to differ in some other leading particular; probably in the absence of acid, or of any basis which can easily be acidified by the action of nitrous or other acids. Much information would no doubt be derived from a careful examination of the products which these several substances afford by combustion.

Conjecture re-
specting its sin-
gular proper-
ties. Page 431
—433-516.

* Neumann's Chemistry, by Lewis, ii. 422. Fourcroy, iv. 447, says that spermaceti forms a soap with caustic alkali; which is contrary to the positive assertion of Neumann, from whom the foregoing part of the text is taken.

PARTS OF
ANIMALS.

Bones.

The bones of men and quadrupeds owe their great firmness and solidity to a considerable portion of the phosphoric salt of lime which they contain. When these are rasped small, and boiled in water, they afford gelatinous matter, and a portion of fat or oil, which occupied their interstices. By destructive distillation they afford alkaline phlegm, a fetid oil, and much volatile alkali; leaving a coal not easily burned. In an open fire, bones are inflamed by virtue of their oil, and emit an offensive empyreumatic smell. The white, friable, and incombustible residue consists chiefly of lime and phosphoric acid in combination. It affords a small quantity of mild mineral alkali by washing with water. This white matter is decomposable by fusion, with mild fixed alkalis, which unite with the phosphoric acid, at the same time that the fixed air converts the lime into chalk. Acids likewise disengage the phosphoric acid, by uniting with the lime. The nitrous or the vitriolic acids are most commonly used in this process.

White residue.

C H A P. V.

CONCERNING THE BILE, THE GASTRIC JUICE, AND
THE ACID OBTAINED FROM ANTS.

THE fluids which remain to be considered, as composing part of animals, are the bile, the gastric juice, and such acids as are obtained by treatment of animal matters.

ANIMAL
FLUIDS.

The bile or gall is a fluid of a yellowish green colour, excessively bitter, and of a faint nauseous smell. It is separated from the blood in a glandular viscus, well known by the denomination of the liver, and in most animals is collected in a vessel called the gall bladder. The gall of oxen is that which chemists have more particularly examined. Its consistence is almost gelatinous; by agitation it forms a froth similar to that of a solution of soap. Water dissolves it in all proportions; and this solution produces the same effect as a solution of soap in scouring cloths. All the acids decompose it, and produce a coagulum, which separates from the watery solution, at the same time that the acid becomes neutralized by a portion of mineral alkali which unites with it. The coagulum, which may be separated by the filter, is thick, viscid, very bitter, and very inflammable. It appears so far of a resinous nature, as to be totally soluble in ardent spirit: hence it follows that the bile consists principally of a soap composed of this matter and the mineral alkali. It also contains a quantity of serum, which

Characters of
the bile or gall.

ANIMAL
FLUIDS.

which causes it to coagulate by heat, or by the action of ardent spirit, and disposes it to putrefy. Ardent spirit takes up the saponaceous matter, and leaves the serum behind.

Destructive
distillation of
the bile.

Destructive distillation separates first an aqueous fluid, neither acid nor alkaline, but disposed to putrefy. Nothing else passes over upon the water-bath. The residue is of a dark colour, very tenacious, like pitch, and totally soluble in water. If the distillation be continued with caution, on account of the swelling of the matter, the products are a yellowish alkaline phlegm, empyreumatic oil, much volatile alkali, and the elastic products consist of fixed and inflammable air. A considerable coal remains, which contains mineral alkali, an earth, which is probably a combination of phosphoric acid and lime, and a small portion of iron.

Biliary concre-
tions.

The nature of the biliary concretions which are formed in the gall bladder, has not yet been completely ascertained. These are found sometimes of an irregular texture, and a brown, black, yellowish, or greenish colour; others consist of transparent crystalline laminæ, sometimes radiated from the centre to the circumference. * Two ounces of biliary calculus, of a grey colour without, and brownish green within, were dissolved in twelve times their weight of pure ardent spirit, by the assistance of a moderate heat. The hot solution being filtered, soon deposited, by cooling, a large quantity of laminated white brilliant crystals, resembling the concrete acid of borax. The

* Fourcroy, in the *Annales de Chimie*, iii. 245.

ANIMAL
FLUIDS.

Examination
of the biliary
calculus.

quantity amounted to near one sixteenth of the whole calculus; and, upon examination, it possessed the following properties:—It was inflammable, and melted by a gentle heat in a spoon, with a smell like wax, and cooled into a brittle substance of a crystallized fracture: a sudden heat volatilized the whole. Water had no action upon it when cold; but boiling water caused it to melt, and float on the surface like an oil, which became concrete by cooling. Caustic alkalis converted it into soap. Nitro~~us~~ acid dissolved it quietly, and the addition of water separated it unaltered. Ardent spirit dissolved it by heat; but the greatest part was separated by cooling. These characters indicate that it is a substance of the same nature as spermaceti. The author * of this valuable discovery has also found that the crystallized gall stones contain this matter still more abundantly; and that it existed in considerable quantity in an human liver which had been exposed to the air for several years, and had lost its volatile parts by putrefaction. The assiduous researches of the same philosopher into the animal œconomy, have detected the same substance, in a saponaceous form, in bodies which had been many years buried under ground.

A considerable number of chemists have examined the properties of the fluid which appears to be the menstruum of digestion in the stomachs of animals. It is certain that in this process the aliments become converted into a soft or pulpy mass, most probably by the action of a solvent, assisted by their own tendency

The gastric
fluid.

* Fourcroy, in the Annales before cited, iii 120.

ANIMAL
FLUIDS.The gastric
fluid.

to spontaneous decomposition at the temperature of the body of the animal. The gastric juice procured from the stomachs of animals which have been kept fasting for a considerable time, appears to differ according to their respective natures. It is thought to possess a solvent power upon animal and vegetable substances, without any preference of affinity; but this last circumstance is scarcely probable. A powerful antiseptic quality is reckoned among its attributes; but there are some reasons to think that in graminivorous animals it has the contrary effect. In these last, more especially, it contains a disengaged acid, which seems to be the phosphoric. And upon the whole, it appears that accurate and decisive experiments are still wanting, to determine the nature of this compounded and variable fluid, which is of such important use in the animal œconomy.

Acid of ants.

Of the acids which are considered as belonging more especially to the animal kingdom, we have already attended to those afforded by milk, by fat, by the stone of the bladder, by silkworms, and by the calcination of blood with an alkali, in the preparation of Prussian blue; it therefore remains only for us to give an account of the acid which is afforded by ants. These animals appear to contain a peculiar acid, in a vessel placed near the hinder part of their bodies*, which they eject when enraged; or moisten their fangs with it, to render their bite more painful. The acid may be obtained by distillation of the ants

* Wiegley's Chemistry, by Hopson, p. 191. On this acid, consult the authors there referred to; and also Fontana, in the Journal de Physique for 1778, part ii.

with

with water, and subsequent pressure of the residue; or the ants may be tied up in a bag, and twice infused in hot water; from which infusion as much acid may be distilled off, as can be had without burning the residue. It may be purified by saturating it with alkali, filtrating, and evaporating part of the liquor, and distilling it with half its weight of vitriolic acid: or, more conveniently, the rectified acid may be exposed to the action of a freezing atmosphere, which congeals its aqueous part. This acid has a considerable resemblance to vinegar when it is diluted. It acts upon, and combines with, alkalis, soluble earths, and metals, and forms peculiar compounds; from which, as well as the order of its elective attractions, its title to be considered as a distinct or peculiar acid is established.

Destructive distillation converts it, like the vegetable acids, into fixed air and inflammable air.

ANIMAL
FLUIDS.

Acid of ants.



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A P P E N D I X.

VARIOUS TABLES USEFUL TO CHEMISTS.

AN ACCOUNT OF THE TABLES.

TABLE I. contains a series of numbers, expressing the comparative heats of bodies. It is copied from Crawford's Experiments and Observations on Animal Heat, and the Inflammation of Combustible Bodies: London, 1788. The principles on which this Table is formed, have been explained in page 14 of our work, and elsewhere. Nothing more need therefore be said, than that the numbers are here reduced to one common standard of comparison, water being assumed

ACCOUNT
OF
TABLES.

Table of comparative heats.

ACCOUNT
OF
TABLES.

Table of
weights.

assumed as unity. As these numbers are deduced from the thermometrical changes undergone by the several bodies in like situations, it is clear that they are of use to indicate those changes, for they will be inversely as the numbers themselves.

TABLE II. contains the weights of different countries, compared in French and English grains. The value of this Table is obvious, and its character may be seen at page 70.

Table of specific gravities.

TABLE III. exhibits the specific gravities of bodies. In compiling this, I had Brisson's Table at the end of Lavoisier's *Traité Elementaire de Chimie*, and Muschenbroek's large Table in his *Cours de Physique*, before me. Some few specific gravities are from other authors, or from experiment. It appeared useless to carry it to more than four places of figures, as the temperatures were not noted, and the various specimens of the same substance often differ in the third figure. These assertions may be thought to require proof: for which reason I shall observe, that by experiment I find that the fifth figure changes at every three degrees of Fahrenheit's thermometer; that lead, tin, and probably all other metals cast out of the same fusion, vary in their specific gravities in the third figure, from circumstances not yet determined, but most likely from the cooling, as is seen in the hardening of steel; that salts, and other artificial preparations, retain more or less of the solvent they were separated from, according to the temperature at which it was effected; and that all parts of organized substances not only differ according to the place of their production, their age, and other circumstances, but

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* Prefa
on, p. x.

likewise from their dryness, moisture, and manner of preservation.

TABLE IV. is taken from the seventh Table of M. Lavoisier's *Traité Elementaire*. I have in another place * mentioned the strong objections which may be urged against the supposed or implied accuracy of these weights, taken to so many places of figures. In that place, as the object of attention was of a controversial nature, it was proper to speak far within compass; but on the present occasion I must observe, that the most accurate practical chemists would consider a true determination of the specific gravities of aerial fluids to three, or even two places of figures, as a great and valuable acquisition; and though I regard this Table as the best we possess, yet in every instance I doubt the accuracy of the third decimal, and in most of them the second. The column of English grains is substituted instead of the weight of a cubic foot French, which occupies that place in the original.

TABLE V. is taken from an excellent Paper of Morveau, in the first volume of the *Annales de Chimie*. The experiments were made by M. Prieur du Vernois upon the quantity of about $15\frac{1}{2}$ cubic inches French, under the pressure of about 27 French inches of mercury, which answer to nearly 28 English. The manner in which this investigation was conducted, does great credit to both the philosophers who were concerned in it: and the Essay itself, of which this Table is the result, is highly deserving of the attention of those

* Preface to the second edition of Kirwan's Essay on Phlogiston, p. x.

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Tables of elec-
tive attractions.

students who wish to know the precautions required in these delicate experiments, as well as of the strict enquirer who may be desirous of knowing how far he may depend on the Table itself.

TABLES VI. to XI. contain in substance the two Tables of *Attractiones Electivæ Simplicis* which are placed at the end of Bergman's Treatise on Elective Attractions, inserted in the third volume of his *Opuscula*, and of which we have had a separate translation into English. They have been since copied into a variety of works, and in most with amendments. I have not however ventured to make any alteration, except such as tended to facilitate the insertion of them in the regular pages of the book, instead of adopting the much less convenient mode of printing on a large sheet to be folded out. Hence it is the arrangement of the columns only which is altered, and repetitions avoided; except that in Table VIII. there is a notice that the perlate acid, vital air, the matter of heat, and siderite, are left ; the reasons for which need not be repeated here. Two inducements rendered it most eligible to retain the Tables, in other respects, the same as Bergman left them. The one was, that they might continue to be Bergman's Tables; and the other was, that, if I had been prepared for the arduous task of composing new Tables, it would have been incumbent on me to have fully stated my reasons for the arrangements I might have adopted; which would have been incompatible with the limits of an Elementary Treatise.

With regard to these Tables, after earnestly recommending the student to peruse the work from which

which they are extracted, it may be observed, that the substances at the heads of the columns are considered as simple, with regard to the facts enumerated in these sketches, and so likewise are the substances inserted in the columns. The order of position denotes that the higher any substance stands in any column, the stronger is its elective attraction to the substance at the head of that column. The under part of each Table exhibits the attractions in the dry way, and must be considered as entirely distinct from the upper part. The horizontal lines between the substances in the columns denote that their positions, or comparative powers of attraction, are well determined; and, whenever these lines are wanting, the positions are more or less conjectural. Hence it may be seen how much remained to be done at the time the great Bergman constructed these Tables.

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Elective attractions.

TABLE XII. exhibits an approximation towards expressing the powers of elective attraction between bodies generally applied. It is evident that the Tables of simple elective attraction express only the order in which the several enumerated substances surpass each other in power to adhere to the common substance at the head of each column; and do not by any means shew what will happen when a compound of two principles is applied to another compound also containing two principles, as in the cases called double elective attraction. We cannot, in fact, decide in circumstances of this nature, unless we are previously acquainted with the sum of the two attractions which tend to preserve the original combinations, and are on that account very expressively denominated by Mr.

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Kirwan quiescent attractions; and also with the sum of the other two attractions which tend to form new combinations, and are by the same chemist called the divellent attractions. Thus, for example, if vitriolated tartar, or the compound of vegetable alkali and vitriolic acid, be presented to the marine salt of lime, we cannot foretel the consequence from any simple Tables, because these will not shew whether the sum of the powers which tend to preserve the union of the alkali and vitriolic acid, and also of the lime and marine acid, be in fact greater or less than those by which the alkali tends to combine with the marine, and the lime with the vitriolic acid, and form the new compound of salt of sylvius and selenite. Hence we see the great advantage which the science of chemistry would derive from an extensive numerical Table founded on experiments of the nature of that now before us. For, in the present instance, we find from the Table, that the vegetable alkali and vitriolic acid adhere with a power expressed by the number 62; while the lime and marine acid adhere with a power denoted by 20. These are the quiescent affinities, and their sum is 82. On the other hand, by the same Table, we find that the attraction between vitriolic acid and lime is 54; and between vegetable alkali and marine acid 32. These are the divellent affinities, and their sum is 86. The latter must therefore prevail; that is, the combinations will be changed by the vitriolic acid melting with the lime, and forming selenite; while the marine acid combines with the vegetable alkali, and forms salt of sylvius.

TABLE XIII. shews the proportion of ingredients

in earths and stones. It is taken from Kirwan's Mineralogy. The extensive and indefatigable researches of this author into all the sources of chemical information, and the numerous additions he has himself made to the science, have enabled him to render this Table more perfect than any which is elsewhere to be met with. Much however remains still to be done, in every part of it, before we can depend on its accuracy throughout; and we hope the author will add the labour of perfecting it, to the other advantages which the scientific world has derived from his exertions.

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Table of ingredients in earths and stones.

TABLE I. The Comparative Heats of different Bodies.

Inflammable air	—	—	—	21.4000
Dephlogisticated air	—	—	—	4.7490
Atmospherical air	—	—	—	1.7900
Aqueous vapour	—	—	—	1.5500
Fixed air	—	—	—	1.0454
Arterial blood	—	—	—	1.0300
Water	—	—	—	1.0000
Fresh milk of a cow	—	—	—	.9999
Venous blood	—	—	—	.8928
Phlogisticated air	—	—	—	.7936
Hide of an ox, with the hair	—	—	—	.7870
Lungs of a sheep	—	—	—	.7690
Lean of the beef of an ox	—	—	—	.7400
Alcohol	—	—	—	.6021
Rice	—	—	—	.5060
Horfe beans	—	—	—	.5020
Spermaceri oil	—	—	—	.5000
Dust of the pine tree	—	—	—	.5000
Peas	—	—	—	.4920
Wheat	—	—	—	.4770
Barley	—	—	—	.4210
Oats	—	—	—	.4160
Vitriolic acid	—	—	—	.4290
Pitcoal	—	—	—	.2777
Charcoal	—	—	—	.2631
Chalk	—	—	—	.2564
Rust of iron	—	—	—	.2500
Washed diaphoretic antimony	—	—	—	.2272
Calx of copper, nearly freed from air	—	—	—	.2272
Quicklime	—	—	—	.2229
Cinders	—	—	—	.1923
Ashes of cinders	—	—	—	.1855
Rust of iron, nearly freed from air	—	—	—	.1666
Washed diaphoretic antimony, nearly freed from air	—	—	—	.1666
Ashes of the elm tree	—	—	—	.1402
Calx of zinc, nearly freed from air	—	—	—	.1369
Iron	—	—	—	.1269
Brass	—	—	—	.1123
Copper	—	—	—	.1111
White calx of tin, nearly freed from air	—	—	—	.0990
Regulus of zinc	—	—	—	.0943
Ashes of charcoal	—	—	—	.0909
Tin	—	—	—	.0704
Yellow calx of lead, nearly freed from air	—	—	—	.0680
Regulus of antimony	—	—	—	.0645
Lead	—	—	—	.0352

TABLE II. The Weights of different Countries,

Place and Denomination of Weight.	Marcoz.	gros.	grains.	F. grains.	E. grains.
Berlin. The marc of 16 loths	—	7	5 16	4408	3616.3
Berne. Goldsmiths weight of 8 ounces	1	—	1 4	4648	3813.2
Berne. Pound of 16 ounces, for merchandise	2	1	1 6	9834	8067.7
The common pound varies very considerably in other towns of the Canton.					
Berne. Apothecaries weight of 8 ounces	—	7	5 26	4454	3654.
Bonn.	—	7	5 6 1/2	4398 1/2	3608.6
Brussels. The marc, or original troyes weight	1	—	— 21	4629	3747.6
Cologn. The marc of 16 loths	—	7	5 11	4403	3612.2
Constantinople. The cheki, or 100 drachms	1	2	3 28	6004	4925.6
Copenhagen. Goldsmiths weight, commonly supposed equal to the marc of Cologn	—	7	5 10 1/2	4438 1/2	3641.2
Copenhagen. Merchants weight of 16 loths	1	—	— 22 1/2	4702 1/2	3857.9
Dantzic. Weight commonly supposed equal to the marc of Cologn	—	7	5 3 1/2	4395 1/2	3606.
Florence. The pound (anciently used by the Romans)	1	3	1 20	6392	5244.
Genoa. The peso sottile	1	2	2 30	5970	4897.7
Genoa. The peso grosso	1	2	3 5	5981	4906.7
Hamburgh. Weight; commonly supposed equal to the Cologn marc	—	7	5 7 1/2	4399 1/2	3609.4
Hamburgh. Another weight	—	7	7 23	4559	3740.2
Liege. The Brussels marc used; but the wt. proved	1	—	— 24	4632	3800.1
Lisbon. The marc, or half pound	—	7	3 34	4318	3542.4
London. The pound troy	1	4	1 1	7021	5760.
London. The pound avoirdupoise	1	6	6 6	8538	7004.5
Lucca. The pound	1	3	— 23 1/2	6350 1/2	5217.
Madrid. The marc royal of Castile	—	7	4 8	4328	3550.7
Malta. The pound	1	2	2 21	5961	4890.4
Manheim. (The Cologn marc)	—	7	5 10 1/2	4402 1/2	3611.5
Milan. The marc	—	7	5 33	4425	3630.2
Milan. The libra grossa	3	—	7 1/2	14364	11784.
Munich. (The Cologn marc)	—	7	5 11 1/2	4403 1/2	3612.3
Naples. The pound of 12 ounces	1	2	3 27	6039	4954.5
Ratisbon. The weight for gold; of 128 crowns	1	6	— 24	8088	6635.3
Ratisbon. The weight for ducats; of 64 ducats	—	7	2 32	4208	3452.
Ratisbon. The marc of 8 ounces	1	—	— 24	4632	3800.1
Ratisbon. The pound of 16 ounces	2	2	4 6	10698	8776.5
Rome. The pound of 12 ounces	1	3	1 14	6386	5239.
Stockholm. The pound of 2 marcs	1	5	7 8	8000	6561.1
Stuttgard. (The Cologn marc)	—	7	5 11 1/2	4403 1/2	3612.6
Turin. The marc of 8 ounces	1	—	— 22 1/2	4630 1/2	3799.
At Turin they have also a pound of 12 of the above ounces. But, in their apothecaries pound of 12 ounces, the ounce is one sixth lighter.					
Warsaw. The pound	1	5	2 12	7644	6271.
Venice. The libra grossa of 12 ounces	1	7	4 2 1/2	8980 1/2	7374.5
Venice. The peso sottile of 12 ounces	1	1	0 24	5676	4656.
In the towns dependant on Venice, the pound differs considerably in each.					
Vienna. The marc of commerce	1	1	1 16	5272	4325.
Vienna. The marc of money	1	1	1 26	5282	4333.3
France. The grain	—	—	— —	1.	1.21895
England. The grain	—	—	— —	0.82039	1.

TABLE III. The Specific Gravities of Bodies.

Pure gold cast	-	19258	Onyx	-	2637
Pure gold hammered	-	19362	Muscovy tale	-	2792
Standard gold cast	-	17486	Common slate	-	2672
----- hammered	-	17589	Calcareous spar	-	2715
Pure silver cast	-	10474	Alabaster	-	2730
Pure silver hammered	-	10511	White marble	-	2716
Standard silver in coin	-	10391	Lime stones from	-	1386
Crude platina in grains	-	15602	----- to	-	2390
Platina purified and fused	-	19500	Ponderous spar	-	4474
----- hammered	-	20337	Fluor spar	-	3180
----- drawn into wire	-	21042	Pumice stone	-	914
----- laminated	-	22069	Green glass	-	2620
Mercury	-	13568	English crown glass	-	2520
Lead fused	-	11352	White flint glass, English	-	3290
Copper fused	-	7788	Another piece	-	3216
Copper drawn into wire	-	8878	White flint glass, for achro-	-	
Brass cast	-	8396	matic uses	-	3437
Brass in wire	-	8544	White glass, French	-	2892
Iron cast	-	7207	Glass of S. Gobin	-	2488
Iron bar	-	7788	Brimstone	-	1990
Steel, soft and not ham-	-		Phosphorus	-	1714
mered	-	7840	Yellow amber	-	1078
Steel hardened	-	7816	Distilled water	-	1000
Tin, English, fused	-	7291	Sea water	-	1026
Tin hammered	-	7299	Common spirit of wine	-	837
Malacca tin fused	-	7296	Spirit of wine, the purest	-	
Malacca tin hammered	-	7306	which can be had by	-	
Bismuth	-	9823	mere distillation	-	820
Nickel	-	8660	Vitriolic ether	-	739
Arsenic, the regulus	-	5763	Nitrous	-	909
Cobalt	-	7812	Marine	-	730
Zinc	-	7191	Acetous	-	866
Antimony	-	6702	Concentrated vitriolic acid	-	2125
Manganese	-	6850	Concentrated nitrous acid	-	1580
Wolfram	-	17600	Concentrated marine acid	-	1194
Diamond	-	3521	Fluor acid	-	1500
Ruby	-	4283	Oil of olives	-	915
Ruby spinel	-	3760	— of sweet almonds	-	917
Topaz, oriental	-	4011	Linseed oil	-	940
Topaz, Brazilian	-	3536	Naptha	-	708
Topaz, Saxon	-	3564	Gum elastic	-	933
Sapphire, oriental	-	3994	Camphor	-	989
Emerald	-	2775	Yellow wax	-	965
Adamantine spar	-	4180	White ditto	-	969
Jargon of Ceylon	-	4615	Spermaceti	-	943
Rock crystal from Mada-	-		Tallow	-	942
gascar	-	2653	Heart of oak	-	1170
Quartz	-	2654	Cork	-	240
Agate	-	2590	Egg new laid	-	1082

TABLE IV. The Specific Gravities of Aerial Substances; the Barometer standing at 30 Inches, and the Thermometer at + 55°.*

Names of Aerial Substances.	Weight of one cubic Inch.		From the Experi- ments of
	French.	Englsh.	
	French grains.	Englsh grains.	
Atmospheric air	0.46005	0.45689	M. Lavoisier.
Phlogisticated air	0.44444	0.44139	The same.
Vital air	0.50694	0.50346	The same.
Inflammable air	0.03539	0.03515	The same.
Fixed air	0.68985	0.68511	The same.
Nitrous air	0.54690	0.54314	M. Kirwan.
Alkaline air	0.27488	0.27299	The same.
Vitriolic air	1.03820	1.03109	The same.

* Strictly the numbers are 29.84 inches and 54.5 degrees; answering to 28 French inches, and 10 deg. of Reaumur.

TABLE V. The Expansions of Aërial Substances by Heat, from the Freezing to the Boiling Points of Water. For every Interval of 20° of Reaumur's, or 45° of Fahrenheit's Thermometer.

Names.	From 32° to 77°.	From 77° to 122°	From 122° to 167°	From 167° to 212°	Total From 32° to 212°
Common air	$1 \frac{1}{22.67}$	$3 \frac{1}{61}$	$2 \frac{1}{49}$	$[3 \frac{1}{37}]$	$1 \frac{1}{67}$
Vital air	$2 \frac{1}{21.2}$	$4 \frac{1}{52}$	$1 \frac{1}{33}$	$[3 + 1 \frac{1}{73}]$	$4 + 2 \frac{1}{69}$
Phlogist. air	$2 \frac{1}{9.41}$	$3 \frac{1}{41}$	$1 \frac{1}{32}$	$[5 + 3 \frac{1}{72}]$	$5 + 1 \frac{1}{62}$
Inflam. air	$1 \frac{1}{11.91}$	$6 \frac{1}{92}$	$[2 \frac{1}{83}]$	$[3 \frac{1}{82}]$	$2 \frac{1}{33}$
Nitrous air	$1 \frac{1}{3.13}$	$9 \frac{1}{60}$	$3 \frac{1}{739}$	$[2 \frac{1}{88}]$	$1 \frac{1}{33}$
Fixed air	$9 \frac{1}{649}$	$3 \frac{1}{699}$	$2 \frac{1}{31}$	$[3 \frac{1}{69}]$	$1 + 1 \frac{1}{63}$
Alkaline air	$3 \frac{1}{38}$	$1 \frac{1}{73}$	$1 + 1 \frac{1}{33}$	$[3 + 2 \frac{1}{69}]$	$5 + 3 \frac{1}{28}$

* * The numbers between brackets are uncertain.

TABLE VI. Simple Elective Attractions.
ACIDS.

In the HUMID WAY.

TRIOLIC ACID	NITROUS ACID.	MARINE ACID.	FIXED AIR.	ACID OF BORAX.	ACID OF AMBER.	ACETOUS ACID DISTILLED.
Barytes	Veg. alkali ?	Veg. alkali ?	Barytes	Lime	Barytes	Barytes
Veg. alkali	Min. alkali ?	Min. alkali ?	Lime	Barytes	Lime	Veg. alkali
Min. alkali	Barytes ?	Barytes ?	Veg. alkali	Magnesia	Magnesia	Min. alkali
Lime	Lime	Lime	Min. alkali	Veg. alkali	Veg. alkali	Vol. alkali
Magnesia	Magnesia	Magnesia	Magnesia	Min. alkali	Min. alkali	Lime
Vol. alkali	Vol. alkali	Vol. alkali	Vol. alkali	Vol. alkali	Vol. alkali	Magnesia
Clay	Clay	Clay	Clay	Clay	Clay	Clay
Metallic calces	Metallic calces	Metallic calces	Metallic calces	Metallic calces	Metallic calces	Metallic calces
Water	Water	Water	Water	Water	Water	Water
Ardent spirit	Ardent spirit	Ardent spirit	Ardent spirit	Ardent spirit	Ardent spirit	Ardent spirit
Phlogiston	Phlogiston	Phlogiston	Phlogiston	Phlogiston	Phlogiston	Phlogiston
N. B. The sulphurous or volatile triolic acid follows the same order in the humid way.	N. B. The fumigating nitrous acid follows the same order in the humid way.	N. B. The dephlogisticated or aerated marine acid follows the same order in the humid way.		N. B. The same order is followed by the acids of sugar of sorrel; tartar; and lemon.	The order in which the metallic calces precipitate each other in acids, is the reverse of that in the column of phlogiston, in Table IX. Consult page 132.	
In the DRY WAY.						
PRUSSIAN ACID.						
Phlogiston	Phlogiston	Phlogiston	In the HUMID WAY.	Lime	Barytes	Barytes
Veg. alkali	Barytes	Barytes	Veg. alkali	Barytes	Lime	Veg. alkali
Min. alkali	Veg. alkali	Veg. alkali	Min. alkali	Magnesia	Magnesia	Min. alkali
Barytes	Min. alkali	Min. alkali	Vol. alkali	Veg. alkali	Veg. alkali	Lime
Lime	Lime	Lime	Lime	Min. alkali	Mjs. alkali	Magnesia
Magnesia	Magnesia	Magnesia	Barytes	Metallic calces	Metallic calces	Metallic calces
Metallic calces	Metallic calces	Metallic calces	Magnesia	Vol. alkali	Vol. alkali	Vol. alkali
Vol. alkali	Vol. alkali	Vol. alkali	Clay	Clay	Clay	Clay
Clay	Clay	Clay	Metallic calces	N. B. The same order both in the humid and dry way is followed by the acids of pear; of arsenic; of benzoic; of sugar of milk; of fat; and of phosphorus: except that phlogiston occupies the first place in the dry way with the arsenical acid.	N. B. The same order both in the humid and dry way is followed by the acids of milk and of ants.	N. B. The same order both in the humid and dry way is followed by the acids of milk and of ants.

TABLE VII. Simple Elective Attractions.

ALKALIS AND EARTHS.

IN THE HUMID WAY.

VEG. ALKALI.	MIN. ALKALI.	CLAY.	LIME.	BARYTES.	MAGNESIA.
Vitriolic acid	This alkali agrees with the vegetable in the order of its attractions, both in the humid and the dry way.	Vitriolic acid.	A of sugar	Vitriolic acid	Acid of sugar
Nitrous acid		Nitrous a.	Vitriolic a.	A. of sugar	Phosphor. a.
Marine acid		Marine a.	A. of tartar	A. of amber	Vitriolic acid
Acid of fat		A. of sugar	A. of amber	A. of spar	A. of spar
Acid of spar		Arsenical a.	Phosphor. a.	Phosphor. a.	A. of fat
Phosphor. acid		Sparry a.	A. of f. of milk	A. of f. of milk	A. of arsenic
A. of sugar		A. of fat	Nitrous acid	Nitrous acid	A. of f. of milk
A. of tartar		A. of tartar	Marine acid	Marine acid	A. of amber
A. of arsenic		A. of amber	A. of fat	A. of fat	Nitrous acid
A. of amber		A. of f. of milk	A. of spar	A. of lemon	Marine acid
A. of lemon		A. of lemon	A. of arsenic	A. of tartar	A. of tartar
A. of ants	VOL. ALKALI.	Phosphor. a.	A. of ants	A. of arsenic	A. of lemon
A. of milk		A. of ants	A. of milk	A. of ants	A. of ants
A. of benzoïn		A. of milk	A. of lemons	A. of milk	A. of milk
Acetous acid		A. of benzoïn	A. of benzoïn	A. of benzoïn	A. of benzoïn
A. of f. of milk		Acetous acid	Acetous acid	Acetous acid	Acetous acid
Acid of borax		A. of borax.	Acid of borax	Acid of borax	A. of borax
Vol. vitr. a.		Vol. vitr. a.	Vol. vitr. a.	Vol. vitr. a.	Vol. vitr. a.
Fuming nitr. a.		Fum. nitr. a.	Fum. nitr. a.	Fum. nitr. a.	Fum. nitr. a.
Fixed air		Fixed air	Fixed air	Fixed air	Fixed air
Prussian acid		Prussian acid	Prussian a.	Prussian a.	Prussian a.
Water		This alkali agrees with the vegetable in the order of its attractions, both in the humid and dry way: but mere heat expels it from the acids of phosphorus, borax, and arsenic.		Water	Water
Fat oils			Fat oils	Fat oils	
Sulphur			Sulphur	Sulphur	Sulphur
Met. calces					

IN THE DRY WAY.

SILEX.					
In the HUMID WAY.	A. of spar. Veg. alkali	Phosphor. acid	Phosphor. acid	Phosphor. acid	Phosphor. acid
		A. of borax	A. of borax	A. of borax	A. of borax
		A. of arsenic	A. of arsenic	A. of arsenic	A. of arsenic
		Vitriolic acid	Vitriolic acid	Vitriolic acid	Vitriolic acid
		Nitrous acid	A. of amber	A. of amber	A. of spar
		Marine acid	Nitrous acid	Acid of spar	A. of fat
		A. of spar	Marine acid	Nitrous acid	A. of amber
		A. of fat	A. of fat	Marine acid	Nitrous acid
		A. of amber	A. of spar	A. of fat	Marine acid
		A. of ants	A. of ants	A. of ants	A. of ants
In the DRY WAY.	Fixed alkali Phosphor. acid Calx of lead	A. of milk	A. of milk	A. of milk	A. of milk
		A. of benzoïn	A. of benzoïn	A. of benzoïn	A. of benzoïn
		Acetous acid	Acetous acid	Acetous acid	Acetous acid
		Fixed alkali	Fixed alkali	Fixed alkali	Fixed alkali
		Sulphur	Sulphur	Sulphur	Sulphur
		Calx of lead	Calx of lead	Calx of lead	Calx of lead

TABLE VIII. Simple Elective Attractions.
COMBUSTIBLE SUBSTANCES AND WATER.

IN THE HUMID WAY.				
WATER.	SULPHUR.	SALINE LIYER OF SULPHUR.	ARDENT SPIRIT	ETHER.
Veg. alkali	Calx of lead	Calx of gold	Water	Ardent spirit
Min. alkali	C. of tin	C. of silver	Ether	Essential oils
Vol. alkali	C. of silver	C. of mercury	Essential oils	Expressed oils
Ardent spirit	C. of mercury	C. of arsenic	Volatile alkali	Water
Mild vol. alkali	C. of arsenic	C. of antimony	Fixed alkali	Sulphur
Glauber's salt	C. of antimony	C. of bismuth	Saline hepar	
Ether	C. of iron	C. of copper	Sulphur	
	Veg. alkali	C. of tin		
	Vol. alkali	C. of lead		
	Barytes	C. of nickel	EXPRESSED OIL	ESSENTIAL OIL
	Lime	C. of cobalt		
	Magnesia	C. of manganese		
Vitriolic acid		C. of iron	Ether	Ether
Vitriolated tartar	Fat oils		Essential oils	Ardent spirit
Alum	Essential oils	Ardent spirit	Fixed alkalis	Fat oils
Martial vitriol	Ether	Water	Vol. alkali	Fixed alkalis
Carrol. sublimate	Ardent spirit		Sulphur	Sulphur
IN THE DRY WAY.				
	Fixed alkali	Manganese		
	Iron	Iron		
	Copper	Copper		
	Tin	Tin		
	Lead	Lead		
	Silver	Silver		
	Cobalt	Gold		
	Nickel	Antimony		
	Bismuth	Cobalt		
	Antimony	Nickel		
	Mercury	Bismuth		
	Arsenic	Mercury		
		Arsenic		

Four of the columns in the original tables of Bergman are omitted in these, viz.

The perlate acid; for which see page 215.

Vital air, which is supposed to have an affinity to phlogiston only.

The matter of heat; for which see pages 6. 21.

The semimetal siderite; for which see page 323.

TABLE IX. Simple Elective Attractions.
PHLOGISTON AND METALS.

IN THE HUMID WAY.					
PHLOGISTON.	CALX OF GOLD.	C. OF SILVER.	C. OF PLATINA.	C. OF MERCURY.	C. OF LEAD.
Nitrous acid	Ether	Marine acid	Ether	Acid of fat	Vitriolic acid
Vitriolic acid	Marine acid	Acid of fat	Marine acid	Marine acid	Acid of fat
Dephl. marine a.	Aqua regia	Acid of fugar	Aqua regia	Acid of fugar	A. of f. of milk
Arfenical acid	Nitrous acid	Vitriolic acid	Nitrous acid	Acid of amber	A. of fugar
Phosphor. acid	Vitriolic acid	A. of f. of milk	Vitriolic acid	Arfenical acid	Arfenical acid
	Arfenical acid	Phosphor. acid	Arfenical acid	Phosphor. acid	Acid of tartar
C. platina	Sparry acid	Nitrous acid	Sparry acid	Vitriolic acid	Phosphor. acid
C. gold	Acid of tartar	Arfenical acid	Acid of tartar	A. of f. of milk	Marine acid
C. silver	Phosphor. acid	Sparry acid	Phosphor. acid	Acid of tartar	Nitrous acid
C. mercury	Acid of fat	Acid of tartar	Acid of fat	Acid of lemon	Sparry acid
C. arsenic	Prussian acid	Acid of lemon	Acid of fugar	Nitrous acid	Acid of lemons
C. antimony		Acid of ants	Acid of lemons	Sparry acid	Acid of ants
C. of bismuth		Acid of milk	Acid of ants	Acetous acid	Acid of milk
C. copper		Acetous acid	Acid of milk	Acid of borax	Acetous acid
C. tin		Acid of amber	Acetous acid	Prussian acid	Acid of borax
C. lead		Prussian acid	Acid of amber	Fixed air	Prussian acid
C. nickel		Fixed air			Fixed air
C. cobalt	Fixed alkali				Fixed alkali
C. manganese	Vol. alkali	Vol. alkali			
C. iron					
C. zinc					
Water					
N. B. In the antiphlogistic theory, the column intitled <i>Phlogiston</i> being taken in a reversed order, will express the elective attractions of <i>Vital Air</i>.					
IN THE DRY WAY.					
	GOLD.	SILVER.	PLATINA.	MERCURY.	LEAD.
C. of platina	Mercury	Lead	Arfenic	Gold	Gold
C. gold	Copper	Copper	Gold	Silver	Silver
Acid of arsenic	Silver	Mercury	Copper	Platina	Copper
C. silver	Lead	Bismuth	Tin	Lead	Mercury
C. mercury	Bismuth	Tin	Bismuth	Tin	Bismuth
C. arsenic	Tin	Gold	Zinc	Zinc	Tin
C. antimony	Antimony	Antimony	Antimony	Bismuth	Antimony
C. bismuth	Iron	Iron	Nickel	Copper	Platina
C. copper	Platina	Manganese	Cobalt	Antimony	Arfenic
C. tin	Zinc	Zinc	Manganese	Arfenic	Zinc
C. lead	Nickel	Arfenic	Iron	Iron	Nickel
C. nickel	Arfenic	Nickel	Lead		Iron
C. cobalt	Cobalt	Platina	Silver		
C. manganese	Manganese		Mercury		
C. iron	Sa. liv. of sulph	S. l. of sulph.	S. l. of sulph.	S. l. sulph.	S. l. sulphur
C. zinc		Sulphur		Sulphur	

TABLE X. Simple Elective Attractions.
METALLIC SUBSTANCES.

IN THE HUMID WAY.

CALX OF COPPER.	CALX OF IRON.	CALX OF TIN.	CALX OF BIS- MUTH.	CALX OF NICKEL.	CALX OF ARSENIC.
Acid of sugar	Acid of sugar	Acid of fat	Acid of sugar	Acid of sugar	Marine acid
Acid of tartar	Acid of tartar	Acid of tartar	Acid of arsenic	Acid of forrel	Acid of sugar
Marine acid	Vitriolic acid	Marine acid	Acid of tartar	Marine acid	Vitriolic acid
Vitriolic acid	A. of f. of milk	Vitriolic acid	Phosphor. acid	Vitriolic acid	Nitrous acid
A. of f. of milk	Marine acid	Acid of sugar	Vitriolic acid	Acid of tartar	Acid of fat
Nitrous acid	Nitrous acid	Arsenical acid	Acid of fat	Nitrous acid	Acid of tartar
Acid of fat	Acid of fat	Phosphor. acid	Marine acid	Acid of fat	Phosphor. acid
Arsenical acid	Phosphor. acid	Nitrous acid	Nitrous acid	Phosphor. acid	Acid of forrel
Phosphor. acid	Arsenical acid	Acid of amber	Fluor acid	Fluor acid	Fluor acid
Acid of amber	Sparry acid	Sparry acid		A. of f. of milk	A. of f. of milk
Sparry acid	Acid of amber	A. of f. of milk		Acid of amber	Acid of amber
Acid of lemon	Acid of lemons	Acid of lemons		Acid of lemon	Acid of lemon
Acid of ants	Acid of ants	Acid of ants		Acid of ants	Acid of ants
Acid of milk	Acid of milk	Acid of milk		Acid of milk	Acid of milk
Acetous acid	Acetous acid	Acetous acid		Acetous acid	Arsenical acid
Acid of borax	Acid of borax	Acid of borax		Arsenical acid	Acetous acid
Prussian acid	Prussian acid	Prussian acid		Acid of borax	Prussian acid
Fixed air	Fixed air			Prussian acid	
Fixed alkali		Fixed alkali		Aerial acid	Volatile alkali
Vol. alkali		Vol. alkali		Volatile alkali	Unctuous oils
Fat oils					Water

IN THE DRY WAY.

COPPER.	IRON.	TIN.	BISMUTH.	NICKEL.	ARSENIC.
Gold	Nickel	Zinc	Lead	Iron	Nickel
Silver	Cobalt	Mercury	Silver	Cobalt	Cobalt
Arsenic	Manganese	Copper	Gold	Arsenic	Copper
Iron	Arsenic	Antimony	Mercury	Copper	Iron
Manganese	Copper	Gold	Antimony	Gold	Silver
Zinc	Gold	Silver	Tin	Tin	Tin
Antimony	Silver	Lead	Copper	Antimony	Lead
Platina	Tin	Iron	Platina	Platina	Gold
Tin	Antimony	Manganese	Nickel	Bismuth	Platina
Lead	Platina	Nickel	Iron	Lead	Zinc
Nickel	Bismuth	Arsenic	Zinc	Silver	Antimony
Bismuth	Lead	Platina		Zinc	
Cobalt	Mercury	Bismuth			
Mercury		Cobalt			
Sal. liv. offulph.	S. l. of sulphur	S. l. of sulphur	S. l. of sulph.	S. l. of sulph.	S. l. of sulph.
Sulphur	Sulphur	Sulphur	Sulphur	Sulphur	Sulphur

TABLE XI. Simple Elective Attractions.
METALLIC SUBSTANCES.

IN THE HUMID WAY.				
CALX OF CO- BALT.	CALX OF ZINC.	CALX OF ANTI- MONY.	CALX OF MAN- GANESE.	CALX OF WOL- FRAM.
Acid of sugar	Acid of sugar	Acid of fat	Acid of sugar	Lime
Acid of sorrel	Vitriolic acid	Marine acid	Acid of sorrel	Vegetable alkali
Marine acid	Marine acid	Acid of sugar	Acid of lemon	Volatile alkali
Vitriolic acid	Acid of f. of milk	Vitriolic acid	Phosphoric acid	
Acid of tartar	Nitrous acid	Nitrous acid	Acid of tartar	
Nitrous acid	Acid of fat	Acid of tartar	Fluor acid	
Acid of fat	Acid of sorrel	Acid of sorrel	Marine acid	In the DRY WAY.
Phosphoric acid	Acid of tartar	Acid of f. of milk	Vitriolic acid	Fixed alkali
Fluor acid	Phosphoric acid	Phosphoric acid	Nitrous acid	Lime
Acid of f. of milk	Acid of lemon	Acid of lemon	Acid of f. of milk	Calx of iron
Acid of amber	Acid of amber	Acid of amber	Acid of amber	Calx of manganese
Acid of lemon	Fluor acid	Fluor acid	Acid of fat	
Acid of ants	Arsenical acid	Arsenical acid	Arsenical acid	
Acid of milk	Acid of ants	Acid of ants	Acid of ants	
Acetous acid	Acid of milk	Acid of milk	Acid of milk	This column is
Arsenical acid	Acetous acid	Acetous acid	Acetous acid	additional. It is
Acid of borax	Acid of borax	Acid of borax		deduced from De
Prussian acid	Prussian acid	Prussian acid	Prussian acid	Luyart's Analysis.
Aerial acid	Aerial acid	Aerial acid	Aerial acid	
Volatile alkali	Volatile alkali			
IN THE DRY WAY.				
COBALT.	ZINC.	ANTIMONY.	MANGANESE.	WOLFRAM.
Iron	Copper	Iron	Copper	Iron
Nickel	Antimony	Copper	Iron	Silver
Arsenic	Tin	Tin	Gold	Tin
Copper	Mercury	Lead	Silver	Lead
Gold	Silver	Nickel	Tin	Antimony
Platina	Gold	Silver		Bismuth
Tin	Cobalt	Bismuth		Manganese
Antimony	Arsenic	Zinc		Gold
Zinc	Platina	Gold		Platina
	Bismuth	Platina		
	Lead	Mercury		
	Nickel	Arsenic		
	Iron	Cobalt		
Saline liv. of sulph.		Sal. liv. of sulphur	Sal. liv. of sulphur	
Sulphur		Sulphur		

TABLE XII. Numerical Expression of Attractions by M. Morveau.

	Vitriolic Acid.	Nitrous Acid.	Marine Acid.	Acetous Acid.	Aerial Acid or Fix. Air.
Ponderous earth	65	62	36	29	14
Vegetable alkali	62	58	32	26	9
Mineral alkali	58	50	28	25	8
Lime	54	44	20	19	12
Volatile alkali	46	38	14	20	4
Magnesia	50	40	16	17	6
Argil. earth	40	36	10	15	2

TABLE XIII. Of the Proportion of Ingredients in Earths and Stones.

Calcareous Genus.

100 Parts.	Calcar.	Argill.	Silex.	Mag.	Wat.	Iron.
Calcareous spar	55	-	-	-	11	<i>a</i>
Gypsum	32	-	-	-	38	<i>b</i>
Fluor	57	-	-	-	-	<i>c</i>
Tungsten	50	-	-	-	-	<i>d</i>
Compound spar	60	-	-	35	-	<i>e</i>
Cruetzewald stone	75	-	-	12	-	<i>f</i>
Calcareous marle	50 to 75	20 to 30	20 to 30	-	-	<i>g</i>
Margodes	50	32	15	-	-	2
Stellated spar	66	-	30	-	-	3
Calcareous grit or sand stone	50	-	-	-	-	<i>b</i>
Swine stone	95	-	-	-	-	<i>i</i>
Pyritaceous limestone	75	14	-	-	-	<i>k</i>
Martial tungsten	-	-	-	-	-	<i>l</i>

a And 34 fixed air. — *b* And 30 vitriolic acid. — *c* 43 acid and water. — *d* 50 acid and iron. — *e* Both earths mild. — *f* Ditto. — *g* And water. — *h* Or more; remainder, silex, argill. and iron. — *i* And petrol. ; remainder, argill. and iron. — *k* And 7 quartz and sulphur, that is, 25 pyrites. — *l* By the dry way only 30, and 50 tungsten.

Barytic or Ponderous Genus.

100 Parts.	
Mild barytes	78 Earth, 20 fixed air, 2 baroselenite.
Baroselenite	84 Earth, 13 vitriolic acid, and 3 water.
Hepatic stone	33 Baroselenite, 33 silex, 22 alum, 7 gypsum, 5 petroleum.

O o

Muriatic

Muriatic or Magnesian Genus.

100 Parts.	Silex.	Calc.	Magnesia.	Argill.	Water.	Iron.
Mild magnesia -	—	—	48	—	22	—*
Keffekil -	50	—	50	—	—	—
Steatites -	80	—	17	2	—	1
Argillaceous steatites -	72	—	17	11	—	—
Chalk of Briançon -	70	—	17	11	—	—†
Soap rock -	70	—	17	13	—	—
Asbestos -	63	11	20	4	—	2‡
Martial asbestos -	62	12	13,7	1,7	—	10,6
Suber montanum -	59	11	24	2,4	—	3,6
Amianthus -	64	6,9	18,6	3,3	—	1,2§
Serpentine -	45	—	23	18	12	3
Talc, Muscovy -	50	—	45	5	—	—

Talc, Venetian - - a larger portion of argill. and smaller of magnesia.

Note. The magnesia and calcareous earths are in a mild state, in all the above stones.

* At a medium, and 30 fixed air. — † And 2 of talc. — ‡ At a medium. — || At a medium. — § And 6 barytes.

Argillaceous Genus.

100 Parts.	Silex.	Argill.	Calcareous	Magnesia.	Iron.	Water.
Pure clay, dry -	63	37*	—	—	—	—
Argillac. marl, dry -	46	27	25 †	—	—	—
Fullers earth -	53	18	5	3	4	17 ‡
Pouzzolana -	57	20	6	—	20	—
Tripoli -	90	7	—	—	3	—
Pure mica -	38	28	—	20	14	—
Martial mica -	34,5	25,5	—	18	22	—
Roof slate or shiftus -	46	26	4 mild	8 mild	14	—
Flagst. or argill. shift. -	36	56	—	—	4	—
Horn-stone -	37	22	2	16	23	—
Killas -	60	25	—	9	6	—
Toadstone -	63	14	7	—	16	—
Zeolyte -	60	20	8	—	—	12 §
Pitch-stone -	65	16	—	—	5	14 ¶

Gronsten - - Horn-stone and mica, or horn-stone and shoerl.

Stellsten - - Mica, quartz and argill.

Binda - - Horn-stone, mica, shoerl, quartz, and pyrites.

Growan - - Argill. mica, and quartz.

* At a medium, when perfectly dry, 63 siliceous. — † Mild at a medium. ‡ And marine acid at a medium. — || White calx of iron. — § At a medium. — ¶ And air.

Siliceous

Siliceous Genus.

100 Parts.	Silex.	Argil.	Calcar.	Magn.	Iron.
Crystal - - -	93	6	1	—	—
Flint - - -	80	18	2	—	—
Petrofalex - - -	72	22	6	—	—
Jasper - - -	75	20	—	—	5
Chalcedonian - - -	84	16	—	—	—
Ruby - - -	39	40	mild 9	—	10
Topaz - - -	39	46	ditto 8	—	6
Hyacinth - - -	25	40	dit. 20	—	13
Emerald - - -	24	60	8	—	6
Sapphire - - -	35	58	5	—	2
Chrysoprasium - - -	95	—	1,7	1,2	0,4 ^a
Lapis lazuli - - -	—	—	—	—	— ^b
Felt spar - - -	67	14	—	8	— ^c
Vesuvian garnet - - -	55	39	6	—	—
Garnet - - -	48	30	12	—	10
Martial garnet - - -	43,6	27,6	10	—	19
Shoerl transparent - - -	48	40	5	1	5
Shoerl black - - -	58	27	5	1	5
Bar shoerl - - -	61,6	6,6	21,6	5	1,6 ^d
Tourmaline - - -	37	45	13	—	5 ^e
Basalt - - -	52	15	8	2	25
Rowley ragg - - -	47,5	32,5	—	—	20
Comp. and cellular lava - - -	47	30	5	—	18
Vitreous ditto - - -	49	35	4	—	12
Another from Lapari - - -	69	22	—	—	9
Black agate of Iceland } nearly as the above }	—	—	—	—	—
Pumice stone - - -	84 or 90	—	—	6 to 15	— ^f
Martial muriatic spar - - -	50	—	—	30 mild	20 ^g
Turkey stone - - -	70	5	mild 25	—	— ^h
Ragg stone - - -	70	5	dit. 20	—	5 ⁱ
Siliceous grit, with calca- } reous cement }	62,5	—	40,37,5	—	—
Siliceous ditto, with ar- } gillaceous cement }	77	20	—	—	3 ^k
Ditto, with ferruginous } cement }	80	5	—	—	15 ^l

^a 0,6 copper, and sparry acid. — ^b 80 martial fluor, 20 gypsum, as I believe. — ^c 11 ponderous. — ^d 5 water. — ^e At a medium.
^f Remainder calcareous. — ^g As I believe. — ^h As I believe.
ⁱ As I believe. — ^k As I believe. — ^l As I believe.

Siliceous Genus continued.

Granite	-	-	{ Quartz, felt spar and mica. Quartz, felt spar and shoerl.
Stellsten	-	-	{ Quartz and mica.
Granitello	-	-	
Rapakivi	-	-	{ Felt spar and mica.
Granitone	-	-	
Murksten	-	-	{ Quartz, garnet, and mica.
Norka	-	-	
Porphyry	-	-	{ Jasper, chert, lava, shoerl containing quartz, felt spar, shoerl, mica, or ser- pentine in a crystalline form.
Pudding stone	-	-	{ Jasper, chert, siliceous grit, or lava, con- taining pebbles of an oval form,
Siliceous breccias	-	-	{ The same ground and contents, but in angular forms.
Gneiss	-	-	{ Quartz, mica, steatites.
			{ Quartz, mica, serpentine.
			{ Quartz, mica, shoerl, steatites, or soap rock.
			{ Quartz, felt spar, mica, serpentine.
Amygdaloides	-	-	{ Jasper, or chert, containing spar or ser- pentine.
Metallic rock of Born	-	-	{ Quartz, clay, and steatites, and felt spar sometimes.
Variolite	-	-	Serpentine, containing various stones,

Proportion of Ingredients in Natural Salts.

Salts.	Acids	Alka.	Earth	Water.
Tartar vitriolate -	31	63	—	6
Glauber's salt -	14	22	—	64
Vitriolic ammoniac -	42	40	—	18
Epsom -	24	—	19	57
Alum -	24	—	18	58
Vitriol of iron -	20	—	—	55
Ditto of copper -	30	—	—	43
Ditto of zinc -	22	—	—	58
Nitre -	30	63	—	7
Cubic nitre -	29	50	—	21
Nitrous ammoniac -	46	40	—	14
Nitrous selenite -	33	—	32	35
Ditto Epsom -	36	—	27	37
Salt of Silviu -	30	63	—	7
Common salt -	33	50	—	17
Sal ammoniac -	52	40	—	8
Marine selenite -	42	—	38	20
Borax purified -	34	17	—	47

25 iron
27 copper
20 zinc,

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